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No. 5 "The History and Description of Clones of Hevea Brasiliensis"
by C. E. T. Mann and C. C. T. Sharp
(published August 1933) ... $2.00

Stiff cover for filing the leaflets ... $1.00

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OF

THE RUBBER RESEARCH INSTITUTE OF MALAYA

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JOURNAL

OF THE

RUBBER RESEARCH INSTITUTE OF MALAYA

VOL. 8 JANUARY 1938 No. 2

EDITORIAL

TAPPING SYSTEMS

The previous issue of this *Journal* contains a paper by Mr. C. C. T. Sharp dealing with the results of the experiment on tapping-systems on Seventh Mile Estate for the third year, June 1935 to May 1936. The present issue contains a further paper by Mr. Sharp giving the results of the same experiment for the fourth year, June 1936 to May 1937, together with another paper by Mr. Sharp, being the substance of a lecture given at the Annual Conference of the Incorporated Society of Planters in September of last year, in which the results of this experiment for the first four years are summarized and discussed. Little need here be added to the editorial comments on the above-mentioned paper in the previous issue (page 2.) In view of the uncertainty as to the behaviour of rubber trees in a lower yield-class, in relation to different tapping systems, further experiments are now being laid down on such rubber trees. It is interesting to record that independent evidence from various sources including these experiments agrees in showing that, so far as the beneficial effect on yield is concerned, resting from tapping need not exceed three months.

COMMERCIAL PLANTING OF NEW CLONES

One of the vexations of agricultural research is the long time which usually must elapse before the results of experiments can confidently be recommended for practical application. This is particularly true for a long-term crop such as the rubber tree. The practical planter who is in a position to use a promising new clone would often like to "back his fancy" by using it for commercial planting, notably in connection with a replanting programme. The advice given by the Institute, however, must be as free from uncertainty as is reasonably possible, and for that reason

the Institute's policy is based on the principle that the value of a new clone can be assessed with sufficient certainty only when the first buddings of the clone are at least 10 years old, and have been tested under a normal tapping-system for not less than five years. In order to speed things up as much as possible it is naturally desirable that the preliminary period of selection and testing should not unduly delay the critical testing of such clones as may be finally selected. There are different ways of setting about this; these are described and discussed in a circular written by Mr. Mann, which has recently been issued from the Botanical Division, and which is reprinted in this issue of the *Journal* for general information.

Report on Mr. Murray's Visit

It is always stimulating to compare planting practices and opinions in different countries. This is particularly true in relation to bud-grafting in its technical and commercial aspects. This was the principal *raison d'etre* of the visit of Mr. R. K. S. Murray, Botanist and Mycologist to the Rubber Research Scheme (Ceylon), to Malaya and the Netherlands East Indies at the end of 1936. Extensive extracts from his report on this visit are therefore included in this issue of the *Journal*. Much in this report will be familiar to many Malayan planters, and to agricultural scientists concerned with rubber-growing. It is valuable, however, that facts or opinions on matters which do not yet command common agreement among all planters, should be seen through the eyes of a visitor from another country, who is able to combine the necessary scientific knowledge to enable him to form an opinion, with a greater freedom from bias or prejudice than the local man is liable to have. It is also of great value to study the way in which differences in soils and other environmental or economic conditions, as between different rubber-growing countries, affect the relative importance of different aspects of rubber-planting. The published extracts from Mr. Murray's report can be read with much profit in these connections, and here it suffices to point out that with regard to the principal object of the visit—yields of bud-grafted rubber in commercial practice—Mr. Murray states that "these results show beyond the possibility of doubt that yields greatly in excess of those to be expected from unselected seedling material at similar ages are being obtained in estate practice, and it is almost certain that appreciably larger yields will be obtained from younger clearings which are planted with better clones."

The Giant Snail

This is one of the most troublesome pests in many districts, frequently causing serious damage both to young rubber plants and to cover plants. A very notable advance in the methods for the control of this pest consists in the discovery—of unknown origin—of the fact that "Meta", material hitherto used primarily as a dry fuel for domestic purposes, for heating kettles and the like, is a deadly poison for these pests. The method of its application, in the form of a bran-bait, and the results of tests carried out at the Institute's Experiment Station, are dealt with in a paper by Mr. Beeley in this issue. The method would prove needlessly expensive as a sole means of keeping the pest in check year-in, year-out; but it seems to be unapproached by any other known method, as a means of rapidly reducing an infestation to a low level such that it can then be kept permanently in check by the use of calcium arsenate-lime-cement bricks.

Oidium Heveae

Mr. Beeley's report on the incidence of Hevea leaf-mildew in 1937 has been purposely held back until this issue of the *Journal* in the belief that it will be read with greater interest at a time when this year's Oidium season is imminent. The climatic conditions during the latter part of 1936 and the early part of 1937 were particularly favourable for the study of the relation between the incidence of this disease and meteorological conditions. On the whole the attack in 1937 was quite a mild one, and there is nothing to indicate that the prevalence or virulence of the disease is on the increase in this country.

Leguminous Cover-Crops

Although leguminous cover-crops can commonly be established with comparative ease in areas of young rubber trees, on the majority of Malayan soils it proves extremely difficult or impossible to establish or retain them in a mature stand. These failures are commonly attributed to the effect of heavy shade. That this cannot be the whole story is amply demonstrated by the fact that in some areas, exceptional but none the less authentic in Malaya, but more particularly in Sumatra, leguminous creeping covers flourish under shade. There must therefore be other factors at work. One of these is now well-recognised to be phosphate-deficiency, and phosphatic manuring may be one of the essential factors for success in the establishment and maintenance of such covers on many soils. A further important factor is that

of the presence of the necessary nodule organism. Without the presence of the correct strain of organism, leguminous plants cannot form the nodules on their roots, on which they normally depend for their supply of nitrogenous plant-food. This aspect of the subject is now being actively investigated at the Institute and this issue of the *Journal* contains a paper by Mr. Beeley, being a reprint of a lecture given at the Annual Conference of the Incorporated Society of Planters in September last, which deals in some detail with the scientific aspects of this subject and with their practical application. It may well be that the effect of shade is the "last straw" for leguminous crops already suffering from deficiency of phosphate and perhaps other mineral nutrients, together with absence of the correct strain of nodule bacteria, and that if these two deficiencies are remedied the establishment and the maintenance of leguminous creepers under mature rubber on Malayan soils will be more generally feasible.

Factory Equipment on Estates

Marked advances have been made in recent years in the design of the equipment in estate factories, particularly with regard to sheeting batteries and smoke-houses. Such progress has now reached the stage that, to quote from the summary of the paper by Mr. Piddlesden in this issue "improvement and economies in the immediate future will be effected by attempts to make the best use of existing types of equipment rather than by violent departures from current designs." The Institute is constantly being asked to advise on the organisation and lay-out of estate factories, and the present paper summarizes the position, and in particular discusses the question of the proper co-ordination, in space and in time, of the various pieces of equipment and machinery, and their working, which are concerned in the conversion of field latex into smoked sheet.

The Composition of Latex

The previous volume of this *Journal* contains the first paper by Dr. Roberts on the results of his work on the composition of Hevea latex. The so-called "non-rubber solids" were shown to consist of, and were separated into, several well-defined fractions, the further study of which promised to throw considerable light not only on practical problems of latex processing and rubber manufacture, but also on the important fundamental problems of the functions of latex in the tree and the mechanism of its formation. This work has now been carried considerably further, and the present issue contains three more papers by Dr. Roberts.

From the technological point of view one of the most important aspects of this work is that of its bearing upon the variability of raw rubber. There is a long-standing desire on the part of the manufacturers of rubber goods for standardization of the raw material, though unanimity regarding the standards required has not yet been evinced. Variability of raw rubber depends partly upon variations in procedure in the estate factory during the conversion of latex into dry rubber, but it depends even more upon inherent variations in the latex itself, as obtained from trees of varying age and origin, on varying soils, and under varying climatic, meteorological, and tapping conditions. Dr. Roberts' work is an important contribution to this latter aspect of the subject, for by the study of the different characteristic fractions of the latex solids and their variation in amount and in composition, it should ultimately prove possible to interpret these inherent variations and the variations in vulcanisation and other properties, in chemical terms. Until the chemical nature of the variations in latex have been elucidated, it is impossible to say with certainty to what extent the effect of these variations could be obviated by changes in the subsequent treatment of the latex, or what the nature of those changes should be.

Modern Field Experiments

Experimental work in the field on the many and varied aspects of the cultivation of Hevea is now wide-spread. Not only is the programme of such experiments which are being carried out by the Institute or under the supervision of its staff, now a very extensive one, but many estates are also carrying on experimental work of their own. Unless proper safeguards are available in the interpretation of the results of experiments, erroneous conclusions may easily be drawn, and if such erroneous conclusions are applied commercially on estates, considerable financial loss may result. During the past 10 or 15 years there has been a virtual revolution in the design and interpretation of field experiments, following the application of mathematical statistics to the subject, in which application R. A. Fisher was the pioneer and is still recognised as the leader. The mathematical considerations involved in the design of modern field experiments, and in the interpretation of their results, are too abstruse to be readily intelligible to any but the professional mathematician. On the other hand the reasons why ill-designed experiments may be so misleading as to be worse than useless, and the general principles underlying the design of modern experiments and the interpretation of their results, can be explained in non-mathematical language.

An attempt has been made to do this in a paper by the Director in the present issue, which is the substance of a lecture given at the Annual Conference of the Incorporated Society of Planters in September last. It is believed that planters who are interested in carrying out experiments, but who are suspicious of the demands of agricultural scientists regarding the way in which such experiments should be laid out, will find that perusal of this paper helps to allay their suspicions; and that it will make them realize that the extra trouble involved in carrying out a properly-designed experiment is likely to be well worth while, by giving them results of a known reliability as compared with the possibility of drawing erroneous and expensive conclusions from wrongly-designed experiments.

Kuala Lumpur,

2nd February, 1938

EXPERIMENTS WITH ECONOMIC TAPPING SYSTEMS (1)

BY

C. C. T. SHARP

Part VI

Results of Tapping for the fourth Year, June 1936 to May 1937, of the Experiment on Seventh Mile Estate

The results of the fourth year of tapping are presented in Tables XXIV to XXIX and Fig. 13. No change has been made in the tapping systems compared or in the method of recording, and these tables are in continuation of the corresponding tables and figures given in the previous accounts of the progress of this experiment. *

The whole experimental area was manured in October/December 1936 with four pounds of sulphate of ammonia per tree. This was the second application of manure, a similar application having been made in September 1934.

From the analysis of variance (Table XXVII) the Standard Error of the difference between two means has been calculated and found to be 25.8 lb. This is a small increase over that of the previous year and differences of less than 52 pounds, or 10 per cent, cannot be regarded as significant.

A full discussion of the results of the first four years of this experiment, including those here presented in detail, is given in a separate paper in this issue of the *Journal*. It will thus be necessary to refer here only very briefly to the results of the fourth year of tapping.

PLOTS 1, 2 AND 3. A.D., A.B.C. WITH THREE, FIVE AND SEVEN MONTHS REST RESPECTIVELY.

Compared with the control the yields again show a small decrease, though the actual yield in lb. per acre has increased slightly. The yields of the three systems remain in the same order, the system with three months' rest still giving a slightly higher yield than the others, while that with the seven months' rest gives the lowest yield. The differences are not significant.

* The previous papers in this series appear in this *Journal*: **5** (1934) 320-341; **6** (1935) 105-110; **8** (1937) 24-38.

Plots 4, 5 and 6. Sunderland system with resting periods of three, five and seven months respectively.

Compared with the control the yields from these plots again show a small increase. They still however lag behind those of the A.B.C. plots.

Plot 7. Double-four A.B.C.D.

So far no response to the resting periods can be recorded, the drop in yield to 25 per cent below that of the control being equal to the reduction in the number of tappings.

This system has been in use only since October 1935 and it will not be possible to form any estimate of its value until the results of the fifth year of the experiment are available.

FIG. 13

TAPPING EXPERIMENT ON 7th MILE ESTATE

PROGRESS OF TOTAL YIELD AS PERCENTAGE OF CONTROL
4th YEAR

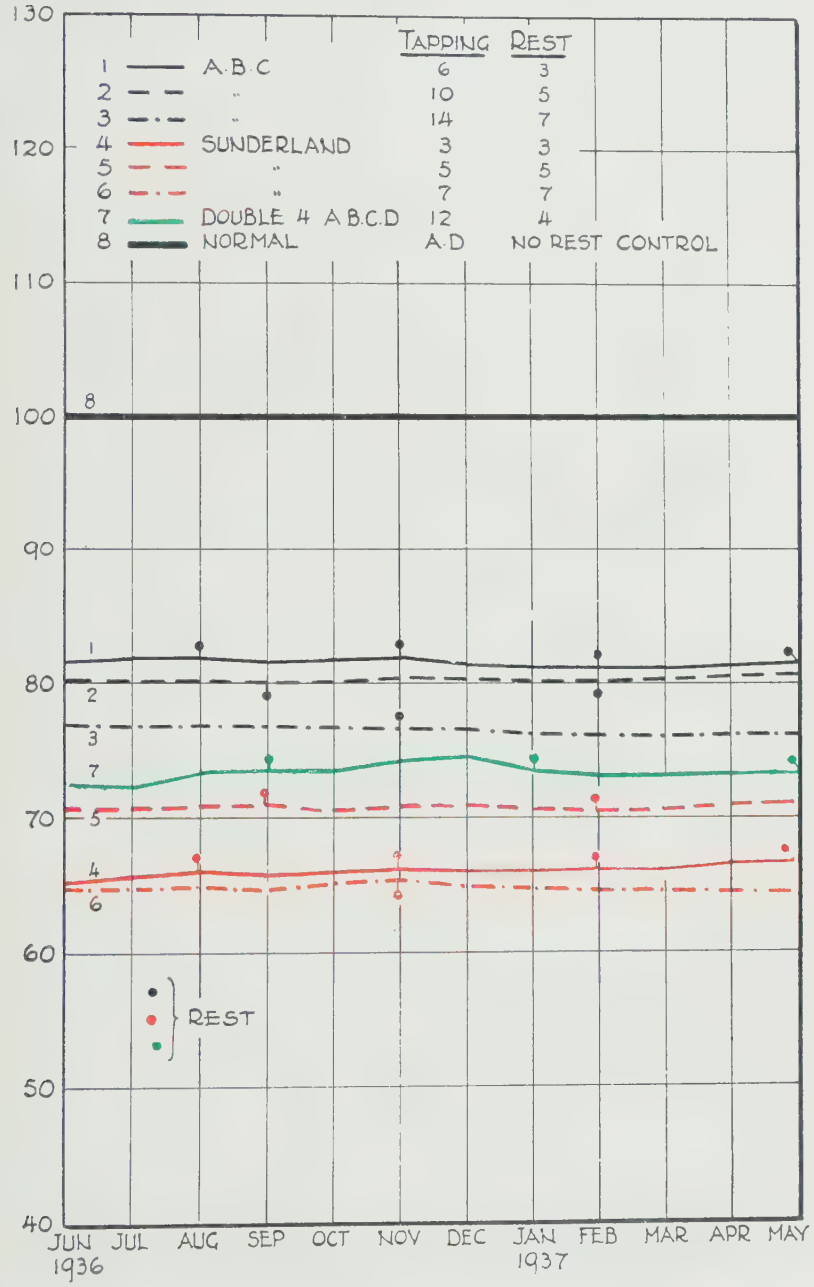


TABLE XXIV

Yields June 1936—May 1937

Total Yield per Plot (lb. dry rubber) excluding Scrap

Blocks	Plots and Tapping Systems							
	1	2	3	4	5	6	7	8
	A.B.C. 6—3	A.B.C. 10—5	A.B.C. 14—7	Sunderland 3—3	Sunderland 5—5	Sunderland 7—7	Double-four A.B.C.D. 12—4	Control
I ...	2,778.0	2,991.2	2,657.5	1,962.2	2,297.8	2,149.9	4,256.4	2,359.2
II ...	3,047.1	2,858.4	2,601.0	2,051.8	2,000.6	2,069.0	4,384.3	2,232.2
III ...	3,060.9	2,957.2	3,040.3	1,835.2	2,428.8	1,721.5	4,062.4	2,318.4
IV ...	2,948.8	3,329.4	2,889.0	2,119.5	2,380.0	1,868.2	4,394.1	2,916.5
V ...	3,259.6	3,074.0	2,968.6	2,499.3	1,957.9	1,891.3	4,442.1	2,183.4
VI ...	2,536.9	2,420.9	2,039.5	1,657.6	1,885.6	1,631.0	3,562.5	2,330.2
Total ...	17,631.3	17,631.1	16,195.9	12,125.6	12,950.7	11,330.9	25,101.8	14,340.0

Grand Total : 127,307.3 lb.

TABLE XXV

Yield in lb. per Acre, for Fourth Year of Tapping, of First-Grade Rubber, Scrap and Total Dry Rubber

June 1936—May 1937

	Block Nos.	Plots and Tapping Systems							
		1 A. B. C. 6—3	2 A. B. C. 10—5	3 A. B. C. 14—7	4 Sunderland 3—3	5 Sunderland 5—5	6 Sunderland 7—7	7 Double-four A.B.C.D. 12—4	8 Alternate-daily (Control)
First-Grade Rubber	I ...	518.6	558.4	496.1	457.8	536.2	501.6	496.6	660.6
	II ...	568.8	533.6	485.5	478.8	466.8	482.8	511.5	625.0
	III ...	571.4	552.0	567.5	428.2	566.7	401.7	473.9	649.2
	IV ...	550.4	621.5	539.3	494.6	555.3	435.9	512.6	816.6
	V ...	608.5	573.8	554.1	583.2	456.8	441.3	518.2	611.4
	VI ...	473.6	451.9	380.7	386.8	440.0	380.6	415.6	652.5
	Mean ...	548.6	548.5	503.9	471.6	503.6	440.7	488.1	669.2
	Per Cent. ...	82.0	82.0	75.3	70.5	75.3	65.9	72.9	100.0
Scrap	Mean ...	51.6	47.7	44.5	59.1	63.1	58.9	65.9	64.1
	Per Cent. of First-Grade Rubber	9.4	8.7	8.8	12.5	12.5	13.4	13.5	9.6
Total Dry Rubber	Mean ...	600.2	596.2	548.4	530.7	566.7	499.6	554.0	733.3
	Per Cent. ...	81.8	81.3	74.8	72.4	77.3	68.1	75.5	100.0

General Mean 521.8 lb. First-Grade Rubber per acre.

TABLE XXVI

Mean Yield in pounds per acre per month of First-Grade Rubber

(Fourth Year of Experiment)

		1 A. B. C. 6—3			2 A. B. C. 10—5			3 A. B. C. 14—7			4 Sunderland 3—3			5 Sunderland 5—5			6 Sunderland 7—7			7 Double-Four A.B.C.D. 12 : 4			8 Alternate-Daily (Control)		
		Yield			Yield			Yield			Yield			Yield			Yield			Yield			Yield		
		Lb.	per cent.	Total per cent.	Lb.	per cent.	Total Per cent.	Lb.	per cent.	Total per cent.	Lb.	per cent.	Total per cent.	Lb.	Per cent.	Total Per cent.	Lb.	Per cent.	Total Per cent.	Lb.	Per cent.	Total Per cent.	Lb.	Per cent.	Total per cent.
June	1936	41.7	81.1	81.7	43.3	84.2	80.2	45.9	89.3	76.8	27.4	53.0	65.1	48.1	93.6	70.7	45.5	88.5	64.7	35.5	69.1	72.5	51.4	100.0	100.0
July	„	47.2	84.0	81.8	44.5	79.0	80.2	42.5	75.6	76.7	45.0	80.1	65.5	41.5	73.8	70.8	37.4	66.5	64.7	39.8	70.8	72.3	56.2	100.0	100.0
August	„	46.6	90.5	81.9	41.5	80.6	80.2	40.7	79.0	76.8	40.9	79.4	65.9	39.8	77.3	70.9	37.5	72.8	64.9	43.6	84.7	73.4	51.5	100.0	100.0
September	„	38.0	71.3	81.7	39.0	73.2	80.0	38.7	72.6	76.7	31.4	58.9	65.7	39.2	73.5	71.0	36.4	68.3	65.0	38.7	72.6	73.4	51.5	100.0	100.0
October	„	48.6	86.2	81.8	46.2	81.9	80.1	43.4	77.0	76.6	41.0	72.7	65.9	30.0	53.2	70.5	39.7	70.5	65.2	40.9	72.5	73.3	56.4	100.0	100.0
November	„	43.4	84.4	81.9	47.4	92.2	80.4	38.6	75.1	76.6	40.9	79.8	66.2	44.7	83.1	70.8	36.6	71.2	65.3	43.2	48.0	74.1	51.4	100.0	100.0
December	„	50.0	74.2	81.6	53.1	78.8	80.3	49.4	73.3	76.5	39.2	58.2	66.0	51.7	76.7	71.0	34.4	51.0	64.9	52.3	77.6	74.4	67.4	100.0	100.0
January	1937	49.0	70.7	81.3	50.6	73.0	80.1	46.3	66.8	76.2	47.2	68.1	66.0	41.5	59.9	70.7	41.3	59.6	64.7	42.5	61.3	73.3	69.3	100.0	100.0
February	„	45.2	78.9	81.2	45.1	78.7	80.1	40.8	71.2	76.1	42.6	74.3	66.2	37.3	65.1	70.5	31.2	54.5	64.5	36.8	64.2	72.8	57.3	100.0	100.0
March	„	42.1	79.7	81.2	45.2	58.6	80.2	38.0	72.0	76.0	30.3	57.4	66.0	38.3	72.5	70.6	35.2	66.7	64.5	38.5	72.9	72.8	52.8	100.0	100.0
April	„	48.2	97.0	81.5	46.8	94.2	80.5	38.8	78.1	76.1	46.2	93.0	66.6	45.8	92.2	71.0	31.5	63.4	64.5	38.4	77.3	73.0	49.7	100.0	100.0
May	„	48.3	91.5	81.7	45.8	86.7	80.6	40.7	77.1	76.1	39.4	74.6	66.8	47.7	90.3	71.4	33.8	64.0	64.5	38.0	72.0	72.9	52.8	100.0	100.0

NOTE. *The thick horizontal lines show the points at which tapped and rested sections were changed over.*

TABLE XXVII

Analysis of Variance. First Grade Rubber (fourth year)

	Degrees of Freedom	Sums of squares	Mean square
Treatments ...	7	204,360.9	29,194.4
Blocks ...	5	63,672.3	
Error ...	35	70,003.3	2,000.9

TABLE XXVIII

Yield per Tapper and Comparative Cost of Tapping (fourth year)

Tapping System	Yield per Tapper per Tapping			Comparative Cost per lb.		Comparative Yield per Acre	
	First-Grade Rubber lb.	Scrap Rubber lb.	Total Dry Rubber lb.	First-Grade Rubber per cent	Total Dry Rubber per cent	First-Grade Rubber per cent	Total Dry Rubber per cent
1	17.0	1.6	18.6	81.2	81.3	82.0	81.8
2	17.0	1.5	18.5	81.2	81.8	82.0	81.3
3	15.6	1.4	17.0	88.5	88.6	75.3	74.8
4	17.6	2.2	19.8	78.4	76.7	70.5	72.4
5	18.6	2.3	20.9	74.2	72.9	75.3	77.3
6	16.4	2.2	18.6	84.1	81.8	65.9	68.1
7	16.2	2.2	18.4	85.2	82.7	72.9	75.5
8	13.8	1.3	15.1	100.0	100.0	100.0	100.0

TABLE XXIX

Mean Dry Rubber Content (fourth year)

Month		Tapping Systems							
		1	2	3	4	5	6	7	8
June	1936 ...	41.8	41.2	39.6	47.7	41.7	41.0	42.6	39.9
July	„ ...	40.9	39.2	38.9	41.3	39.1	38.9	41.8	39.3
August	„ ...	40.0	40.0	40.3	41.2	41.2	40.4	42.4	41.1
September	„ ...	43.1	40.2	39.7	48.1	39.3	39.4	41.2	42.1
October	„ ...	40.5	41.3	38.1	42.0	44.6	38.5	43.2	38.5
November	„ ...	38.4	39.1	37.8	39.9	41.5	38.4	41.5	38.8
December	„ ...	42.3	38.8	42.9	47.2	39.2	48.7	40.4	40.1
January	1937 ...	41.4	39.1	40.5	40.8	38.3	43.0	40.6	39.3
February	„ ...	40.4	39.7	38.6	39.8	38.9	40.3	43.4	39.8
March	„ ...	42.0	42.2	38.8	47.4	47.4	40.0	41.8	40.0
April	„ ...	39.3	39.3	37.3	40.5	40.0	38.3	39.5	38.6
May	„ ...	38.7	39.2	37.5	39.5	38.3	38.8	40.6	39.3

Note. The thick horizontal lines show the points at which tapped and rested sections were changed over.

Kuala Lumpur

22nd December, 1937

EXPERIMENTS ON TAPPING SYSTEMS*

BY

C. C. T. Sharp

In May 1933, a large-scale tapping experiment was set up on Seventh Mile Estate. At that time we were in the depths of the world slump and the price of rubber was equal to roughly one-sixth of the price at the present day. Attention was consequently fixed very largely on methods by which the costs of production might be lowered. One method by which it was hoped that this could be done was by means of modifying the standard tapping systems of the day with the object of reducing the cost of tapping, which at that time amounted to from 25 to 40 per cent or even more of the total value of the rubber. In this experiment it was therefore decided to compare various tapping systems which showed promise of reducing the cost of tapping, and at the same time to set up the experiment in such a way that an accurate estimate of the tapping costs could be obtained.

The tapping systems compared fall into two groups, those with a single cut and those with a double cut. The single-cut systems consist of the standard alternate-daily system without rest, which is used in this experiment as the control. In addition, there were three types of A.B.C. tapping systems with three, five and seven months rest followed by double the period of tapping on alternate days on a half-circumference. The double-cut systems used originated in Ceylon where they arose as a natural development of the change-over system in common use there by the simple expedient of continuing tapping on both cuts and introducing rest periods. Their introduction into this country was, it is believed, effected by Mr. S. B. Palmer of Bruas Estate and Mr. Jack Murray.

The object of the double-cut system is to use the tappers' time more economically. The time spent in tapping can be divided into two parts, that spent in the actual tapping of the trees and that spent in walking from tree to tree. Since, from the point of view of the Estate, the time spent in walking is time wasted, it was argued that if a tapper could tap two cuts on each tree instead of one he would be able to halve the time spent in walking, and that he should in consequence be able to make a small additional number

* The substance of a lecture given at the Annual Conference of the Incorporated Society of Planters held at Kuala Lumpur on 17th September, 1937.

of cuts and still finish his task at the same time. Provided there is no loss in crop this should enable him to tap more cheaply.

The double-cut systems employed are the Sunderland and the Double-four. The former consists of tapping two half-circumference cuts, one on each side of the tree, every third day for a certain period, which would be followed by an equal period of rest. Three plots of this system with tapping and resting periods of three, five and seven months are included in this experiment.

The last treatment, the Double-four, consists of tapping every fourth day on two cuts with no long period of rest.

The eight tapping systems consist therefore of three A.B.C., three Sunderland, all with 120 tappings on a half-circumference in a full year; and the Double-four and A.D. with 180 tappings.

One of the advantages of systems such as the A.B.C. is the lower bark-consumption and consequently the possibility of keeping the tapping cuts at a lower level. A ten-year cycle of tapping was fixed and the cuts of each tapping system were opened as low down the stem of the tree as possible consistent with this fixed period of renewal.

The experiment was set up on Seventh Mile Estate on an area of over 240 acres of rubber trees planted in 1912. The stand per acre at the commencement of the experiment amounted to 70 trees and the trees were exceptionally well grown. The tapping system in use before the experiment started was A.D. for four years followed by one year's rest. In addition, the whole Estate was rested for one month every year during refoliation after wintering. At the commencement of the experiment (in 1933) the tapping cuts had reached ground level and the whole area was due for a rest of one year.

This area is exceptionally high-yielding, the average yield for the three years immediately before the experiment started being nearly 850 lb. per acre per annum.

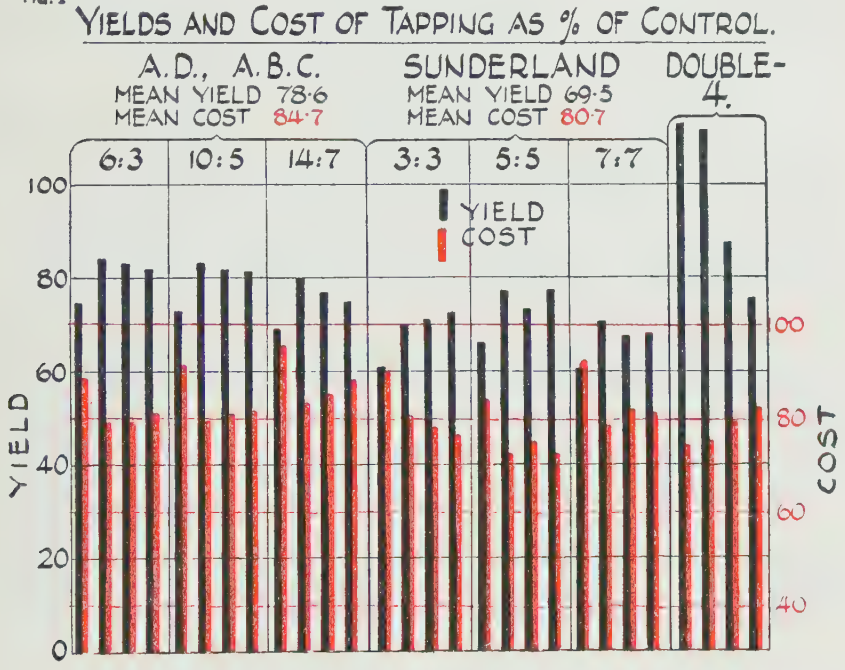
During the second and fourth year of the experiment the experimental area was manured with sulphate of ammonia at the rate of 4 lb. per tree. This was considered by the Manager of the Estate to be necessary, since a deterioration in the foliage of the trees was apparent though no decline in yield had occurred.

The experiment was laid out in the " Randomised Block " form with six replications. Each plot contained a sufficient number of trees to provide a full tapping task together with the trees in rest. A full tapping task amounted to 250 trees in the case of a single-cut task and 150 trees in a double-cut task. Thus, in the A.B.C. plots there would be 375 trees, 250 in tapping and 125 in rest. Similarly, the Sunderland plots would contain 300 trees, 150 in tapping and 150 in rest.

YIELD AND TAPPING COSTS FOR THE FIRST FOUR YEARS

The yields and the costs of tapping of the various tapping systems for each of the first four years, *i.e.* June 1933 to May 1937 are shown in Fig. 1. The standard error has been calculated and differences of less than 8 per cent are not significant. In this histogram the vertical black columns show the annual yields of the seven tapping systems as a percentage of the control. The red columns, adjacent to the black columns, show the comparative cost of tapping also as a percentage of the control.

FIG. 1



Comparing the A.B.C. plots with the A.D. it is clear that the maximum yield was reached in the second year and that thereafter there appears to have been a slow but steady decline. The differences in yield between the three types of A.B.C. tapping are not significant; that is to say, they might have occurred by chance. It is noticeable, however, that the yield varies in the reverse order to the resting periods, the maximum yield being obtained with the shortest periods of rest and tapping. The saving in tapping costs during the last three years amounted to about 18 per cent.

The Sunderland system plots show an average loss of crop of over 40 per cent when compared with the control, or 11½ per cent

when compared with the A.B.C. plots. Comparing the best of the three plots, that with five months tapping and five months rest, with the best of the A.B.C. plots with three months rest, the loss in crop is 8 per cent and the saving in tapping costs 9 per cent. This loss would not be compensated for by the slightly cheaper tapping costs, and on these grounds the A.B.C. system has shown itself the better.

The last system, the Double-four, started off very well with a higher yield than the control and a 25 per cent saving in tapping costs. The higher yield, and in consequence a part of the saving in tapping costs, can be accounted for by the lower average height of the tapping cuts, and if it had been possible to continue this system to the end of the five years of the experiment, as was originally intended, a less favourable result would have been expected. But even then it is very unlikely that there would have been a saving of less than 20 per cent in tapping costs over the whole period.

It was found, however, that it was impossible to keep the bark consumption down to the programme of 9 inches a year, 4½ inches on each panel, the excess consumption being about 2 inches a year. We were therefore compelled to abandon this system after 28 months and to convert it to Double-four A.B.C.D. with four-monthly resting periods. It will be necessary to wait until the yields of the fifth year are available before any estimate of the value of this tapping system can be made.

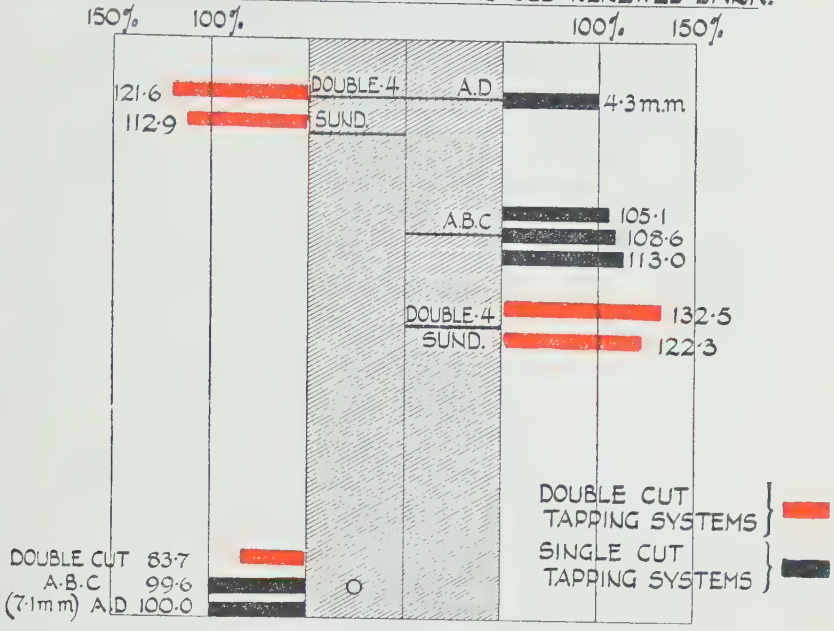
One further disadvantage of the double-cut tapping systems is the high proportion of scrap rubber, which exceeds that of the control by 25 per cent in the Sunderland plots and by over 40 per cent in the Double-four plots.

Bark Renewal

The first measurements of the thickness of the renewing bark were made on three years' renewal and the results of these measurements are shown in Fig. 2. In this diagram the shaded area represents a plan of the tapping panels and the horizontal black lines indicate the heights of the various tapping cuts at the commencement of the experiment. The red and black horizontal lines projecting from the sides of the shaded area show the comparative thickness of the renewed bark of the different tapping systems. For convenience, the double-cut tapping systems are shown in red, the single-cut systems in black.

FIG. 2

COMPARATIVE THICKNESS OF THREE-YEARS-OLD RENEWED BARK.



When this experiment was started, the original tapping cut had reached ground level and new cuts were opened for all the systems compared. One further measurement was therefore made at the foot of the panel on which tapping had just been completed when the experiment was commenced, at the point marked with a circle in the diagram. The bark at this point was three years and nine months old.

The standard errors have been calculated and differences of less than 8.5 per cent in the thickness of the three-year-old renewal and of 4.1 per cent of the three-years-and-nine-months' renewal are not significant.

The A.B.C. plots showed a mean increase in the thickness of the renewed bark of 9 per cent. The thickness of the renewal with this system is significantly better than that of the control. This does not, however, mean that the greater thickness of renewal found in this system is solely the result of the resting periods, for it is known that the bark of a tree is thicker the lower down the stem the measurements are taken. That the rate of bark renewal increases with the lowering of the height of the tapping cut is borne out by the difference in the thickness of the renewed bark on the upper and lower panels of the double-cut systems. In the Double-four system the renewal of the bark above the lower cut is about 10 per cent thicker than that above the upper cut which was opened 23 inches higher up. A part at any rate of this

increase in thickness can therefore be accounted for by the difference of 14 inches in the heights of the tapping cuts in the A.B.C. and A.D. tasks.

That the real difference, if any, is very small is confirmed by the measurements at the foot of the opposite panel. The renewed bark of the A.B.C. plots at this point did not differ from that of the A.D. plots at the corresponding point by more than one per cent.

There is, however, another point to be noticed. The thickness of the bark of the three systems differs by a small amount, those with the longer rest-periods giving slightly thicker renewal than those with the shorter ones. The order of merit of the rate of bark renewal is in the reverse order to that of yield, since it was found that the systems with shorter rest-periods gave slightly higher yields than systems with longer rest-periods.

With the double-cut systems the position is very different. When a tapping cut is opened, the normal downward flow of the food material through the sieve tubes is interfered with over half the circumference of the tree. If two cuts are opened, one on each side of the tree, a partial ringing effect is produced. This causes an accumulation of food-stuffs above the tapping cuts and consequently a localised increase in growth in those parts of the tree where the most recently tapped bark is renewing. A similar phenomenon is of common occurrence in young vigorously growing trees during the first year or two of commercial tapping. This localised increase in growth is shown very clearly in the double-cut plots. The thickness of the three-year-old renewed bark above the upper cuts of the Sunderland system plots is 13 per cent. higher than that of the control, and in the Double-four plots 21 per cent. higher. The corresponding figures above the lower cuts are even more striking, being 22 and 33 per cent. respectively.

Below the tapping cuts the position is reversed, and since a part of the food supply is cut off the rate of renewal is retarded. Consequently we find that the bark at the foot of the tree is 16 per cent thinner than the bark of the single-cut plots in the corresponding position. This retardation of the renewal is a serious defect and at first sight it would appear to condemn all double-cut systems completely. On the other hand the bark at the foot of the panel below the upper cuts of the double-cut systems had none the less reached a thickness of 6 m.m. in $3\frac{3}{4}$ years, which may easily be sufficient for all practical purposes. Whether it will prove sufficient or not can be settled only when the time comes to tap the bark at the base of the tree.

Discussion

It must be emphasised that the conclusions to be drawn from this experiment are not necessarily of universal application. The experimental area is exceptional in that it has never suffered from the very severe tapping systems to which so much rubber of the same age has been subjected in the past. It is also exceptionally high-yielding and has yielded on high cuts from 660 to 730 lb. per acre per annum during the four years of the experiment when tapped on the normal alternate-day system on half-circumference without rest.

The Sunderland system can be taken first. The only advantage to be found in this system is that the tapping costs are about five per cent lower than with the A.B.C. system. Against this must be set the high bark consumption of eight inches a year compared with six inches on A.B.C., some doubt about the adequacy of the bark renewal and a loss of crop compared with A.B.C. of 11½ per cent. This system may therefore be accounted a failure and unlikely to be of any practical value.

The Double-four is more satisfactory. The high yields obtained during the first two years are probably in part accounted for by the lower average height of the tapping cuts and might not have been maintained if the full period of five years had been completed, as was originally intended. The saving in tapping costs of 25 per cent may be accounted very satisfactory. The objections are the high bark consumption, which we were unable to keep below eleven inches a year, the high proportion of scrap rubber, equal to nearly half as much again as on the control plots, and the doubt as to the adequacy of the bark renewal at the base of the tree below the tapping cuts. If, however, the doubts as to the renewal can be allayed this system may be found to be very useful should the price of rubber again drop to the 1932—1933 level. It must be again emphasised that the only satisfactory test of the renewal is the tapping test and we could not at present advise estates to adopt this system on more than an experimental scale.

Three years ago, in a paper (1) read before the Annual Conference of the Incorporated Society of Planters, were described the results obtained from a survey of the yields recorded on changing-over to A.B.C. tapping from A.D. without rest. Records from 139 separate sources were studies, and two conclusions could be drawn. The first was that the response to rest in the form of increased yields was greater in the lower-yielding areas than in the higher. It was found that areas of rubber which yielded on the average 425 lb. per acre on A.D. tapping would yield on the A.B.C. system about 92 per cent during the first three years. On the other

hand, rubber capable of an average yield of 675 lb. per acre only yielded 72½ per cent over the same period. The results of the first three years of tapping on Seventh Mile Estate show good agreement with the latter figure. The yield of the alternate-daily plots was 681 lb. per acre and the yields of the three A.B.C. plots 80 per cent, 79 per cent and 75 per cent for the three types with three, five and seven months' rest respectively.

The agreement between the figures obtained from Seventh Mile Estate and the figures from the summary is very satisfactory, but it cannot be claimed that the yields themselves are satisfactory. Reference to Fig. 1 will show that the yields of the A.B.C. plots reached a little over 80 per cent. in the second year, and thereafter showed a small but steady decline during the third and fourth years. This decline can be accounted for by the progressive reduction in the difference in the heights of the tapping cuts of the A.B.C. and the A.D. plots.

At the beginning of the experiment the tapping cuts of the different plots were opened at varying heights with the object of allowing an equal period of bark renewal for all the tapping systems. The A.B.C. plots were therefore opened at 14 inches below the A.D. plots, and at the end of the fourth year the distance between the heights of the cuts of the two systems had been reduced to about 3 inches. This loss of advantage in tapping height could therefore account for the decline in the relative yields of the A.B.C. plots.

It was originally claimed by the first planters to adopt this system of tapping that the yield would, in the course of a few years, recover to the A.D. level and that much better bark renewal would be found as a result of the resting periods. It is clear that with high-yielding rubber the original A.D. yield will not be obtained. With regard to the bark renewal it has been shown that there is only a very small increase in the thickness of the three-year-old renewed bark and it is possible that a part of this increase is caused by the lower height of the tapping cut and not by the resting periods.

From the results of this experiment it seems fair to draw the conclusion that with high-yielding rubber, A.B.C. tapping results in a loss of crop without any adequate compensation in the form of improved bark renewal or lower tapping costs. From the survey of A.B.C. tapping to which reference has already been made it appears that a yield during the first three years of over 80 per cent of the yield on A.D. will not be obtained from rubber capable of yielding more than 500—550 lb. per acre on an alternate-day tapping system.

The position with regard to bark renewal with old lower-yielding rubber is not so clear; it is possible, and it has been frequently claimed, that the renewal is more rapid as a result of periods of rest, and although this is not found with high-yielding rubber it may be the case with lower-yielding.

Whether it is economically sound to improve the rate of bark renewal by resting is another question. There are other alternatives, such as manuring, which has been shown to be capable of giving greatly improved renewal provided it is carried out in time.

The second conclusion that could be drawn from the survey of A.B.C. tapping was that a resting period of twelve months followed by a period of two years' tapping was inferior to the more usual one of six months' resting period followed by a year's tapping. In fact the yields of each yield group were almost identical during the first year of tapping after a rest, whether the rest was for six months or for twelve. It was clear from this that there was a limit to the length of a resting period beyond which further resting was not profitable, and that twelve months was in excess of that limit. It could not however be said whether the optimum period was more or less than six months.

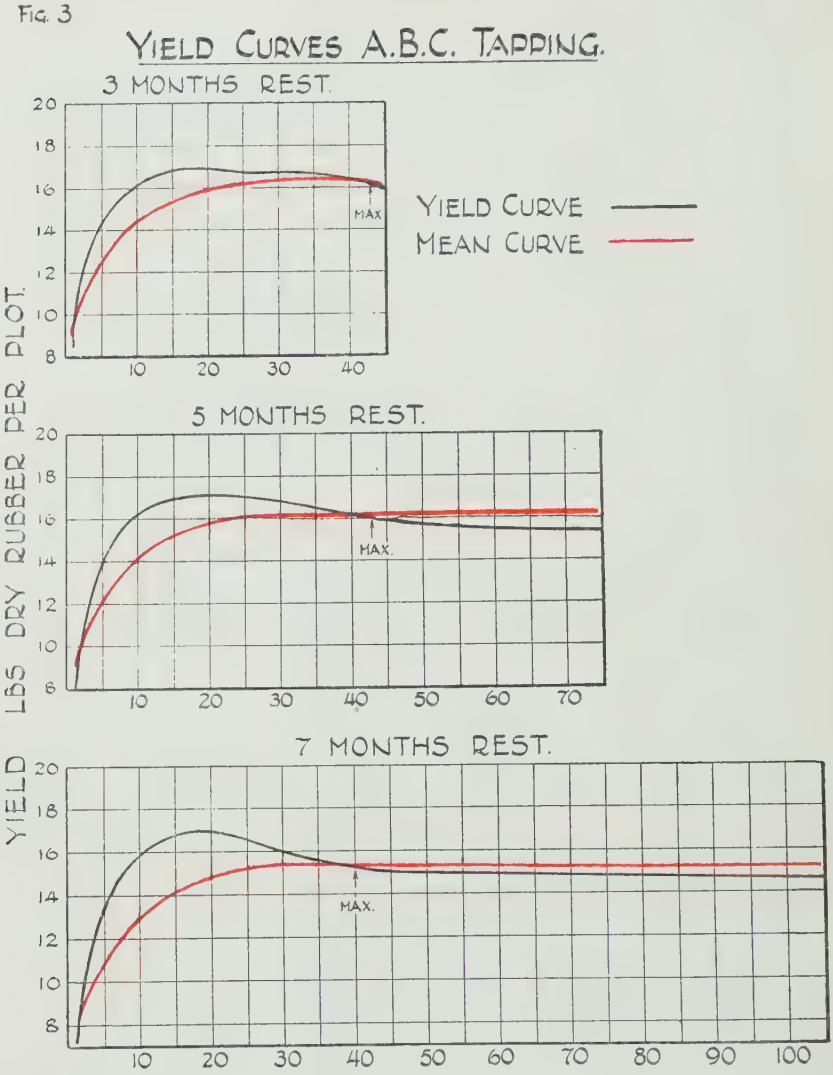
It was in an endeavour to throw more light on the question of the optimum periods of tapping and rest with the A.B.C. system that three plots with three, five and seven months' rest were included in this experiment. The results shown in Fig. 1 indicate that the yields were highest when the resting period was three months and that lengthening the resting period to five and seven months lowered the yield progressively.

The differences are not significant; that is to say they might reasonably be expected to have occurred by chance. For this reason the yield records have been analysed in a different way.

The plots of treatment 1 are tapped for six months and rested for three months; the tapping of these plots for the first four years therefore falls into sixteen series of three months with forty-five tapping days each. The first day of each series is the day on which a rested area comes into tapping and the forty-fifth day the last tapping day before the next change-over.

The mean yield of the first tapping day of the sixteen series has been calculated and plotted on a graph. The calculation was repeated with each of the remaining forty-four tapping days and the smoothed curve shown in black in Fig. 3 was obtained. It will be seen that the curve rises rapidly and reaches a maximum on about the fifteenth tapping day, after which it falls off gradually and is apparently still falling off by the forty-fifth tapping day when the next change-over becomes due.

Fig. 3



The most economic period of tapping must be the one that gives the highest mean yield per tapping. To find this the method used by Hoedt (2) in his investigations on periodic tapping systems has been adopted and the progressive mean of the forty-five tapping days has been calculated. The curve has been plotted in red on the graph in Fig. 3. The progressive mean is found by taking the total yield to-date and dividing it by the number of tappings. On the first day the yields are the same and the two curves will therefore start at the same place. On the second tapping day the average yield for the first two tappings is calculated, on the third day the average for the first three tappings and so on up to the forty-fifth tapping day.

It will be seen that this mean curve rises steadily but less steeply than the daily-yield curve until it also reaches a maximum, but since the yield from an area that has just been rested is always very low for the first few tappings the maximum value of the mean-yield curve will always occur later than the maximum value of the daily-yield curve. In this case the maximum mean yield is reached on the 43rd tapping day, indicating that about three months' rest is the optimum period of rest with the A.B.C. tapping system for rubber of this type.

A similar calculation has been made from the other two A.B.C. plots and the maximum height of the mean-yield curve is found to occur on the 43rd and 40th days for the plots with five and seven months' rest respectively. The fact that the optimum periods are almost identical after periods of three, five and seven months' rest may be taken as conclusive evidence that there is a definite limit to the beneficial effect of rest on yield, and that extending the rest beyond that period will, owing to the necessity of extending the tapping period correspondingly, result in a loss of crop. It may also be concluded that for rubber of this type the optimum period of rest is just about three months.

Having found that with high-yielding rubber of this sort the optimum period of resting is about three months it will be interesting to consider the position in greater detail.

Trees manufacture their food-stuffs with the aid of sunlight from the raw materials obtained from the soil and from the air. The food-stuffs so produced are used for growth, in which term is included not only the increase in size of the tree but all its vital activities such as the production of fruit, the replacement of the leaves after defoliation, the manufacture of latex and repair or replacement of damaged tissues.

Hevea differs from the majority of trees in that it has a system of living cells, the latex vessels, in which latex is manufactured.

It is therefore possible to consider the manufacture of latex by the rubber tree separately from all the other vital activities which may be referred to collectively as growth. So long as the tree is alive both these activities are going on, but the proportion of the energies of the tree devoted to each activity can be made to vary within quite wide limits. The records of the test-tapping of Clone B.84 on Pilmoor Estate provide a good instance of this. The trees of this clone were first tapped in 1928, and in 1929 the trees were divided into two groups in such a way that the mean girth of the trees in each group was the same. One group was then tapped daily in alternate months and the other group alternate-daily. After eight years it was found that the total yield obtained from the group tapped D.A.M. was 11 per cent higher than that

of the group tapped A.D. On the other hand the increase in girth of the group tapped D.A.M. was 6 per cent less than the increase in the A.D. group. It would seem that the increase in yield with the D.A.M. system has been obtained at the expense of part of the growth of the trees, or to put it in another form, part of the resources of the tree which, if it had been tapped A.D. would have been used for growth, have been used up in making the additional latex extracted from the tree with the D.A.M. system, with a consequent slowing down of the rate of growth.

In a recent paper Schweitzer (3) has summarised the results of a number of experiments to investigate the physiological aspect of the production of latex by Hevea. He was able to show that the first effect of resting a tree after a long period of tapping was a steady and rapid rise in the dry-rubber-content of the latex in the latex vessels, which lasted for about three months. During the fourth month the rise was very small and by the fifth month it had ceased completely. When the tree had reached this condition the manufacture of latex ceased entirely except for the small amount required in the production of new latex vessels.

When the tree was again brought into tapping the dry-rubber-content fell steadily, and by the end of three months a state of equilibrium was reached when the rate of manufacture of the latex was equal to the rate of its withdrawal from the tree. By that time the whole of the effect of rest on yield had worn off. Since the manufacture of latex ceases after the tree has been in rest for more than three months and since it again takes a similar period of three months tapping to restore the conditions that existed before the rest period, it would be expected that extending the resting period to more than three months would have no effect on the subsequent yields. Schweitzer was able to demonstrate this from four different fields which were brought into tapping after a rest of nineteen months. In each case the yields fell to the level obtaining before the rest by the end of the third month of A.D. tapping.

The results of the Seventh Mile Experiment confirm both Schweitzer's and the Pilmoor results. It has been shown that the yield-curve during the first three months of tapping after rest is the same whether the rest period has been three, five or seven months. That is to say, on the cessation of tapping the latex system can be completely filled within three months and extending the period of rest will not cause a greater accumulation of latex in the tree.

When once the latex system has acquired the full quantity of latex it would be able, if the rest were extended, to devote the whole of its energies to growth; it would therefore be expected

that better growth would occur with those tapping systems having the longer rest-periods, and that this is the case is shown by the small but significantly greater thickness of the renewing bark in those plots with the longer rest-periods.

Schweitzer's and the Seventh Mile results confirm those found from the A.B.C. tapping survey to which reference has been made, when applied to high-yielding trees. They do not, however, explain why much more favourable results were obtained with A.B.C. tapping in lower-yielding areas.

It has already been shown that the continuous formation of rubber by the tree occurs only in response to tapping, that is to say, as the result of lowering the concentration of rubber in the latex vessels. It has also been shown by Arisz (4) that the rate of formation of rubber is increased as the concentration is lowered.

If the trees are over-tapped a larger proportion of the available food manufactured by the tree is diverted to the formation of latex and less is available for growth, which in extreme cases may be reduced to a minimum.

Now the rate of food-manufacture by the tree is slower in poor than in good conditions. It follows from this that there can be no universal optimum tapping system, for a system such as A.D. which is well within the capacity of strongly-growing trees may be too heavy in poorer conditions

Schweitzer also reported that one of the first results of resting trees growing in poor conditions was an increase in the number of the latex vessels. This in itself would not only have a big influence on the yield obtained after a resting period but would tend to maintain the yield for a longer period, since the facilities for manufacturing latex would be increased.

A further result of resting poor-yielding rubber is the relatively greater increase in concentration of latex in the latex vessels, as a result of the lower level of concentration at which equilibrium is attained when the effect of rest has worn off. This would produce a bigger flush crop when the trees are again brought into tapping. It is for these reasons that more favourable results are found when low-yielding trees are changed over from A.D. to a lighter system such as A.B.C. than is the case when the same change is made with high-yielding trees.

For these reasons and also on account of the slower rate of food manufacture, it would be expected that the optimum length of the rest-period would be longer with low-yielding trees and would exceed the period of three months found suitable with trees growing under better conditions.

Summary and Conclusions

It has been shown that the Sunderland system was a failure on the high-yielding trees in the experimental area owing to the poor crop and that the Double-four, though very economical in tapping cost, was of doubtful value owing to its high bark-consumption, high proportion of scrap and possibly inadequate bark-renewal.

It also appears from these results that the trees in this experimental area are quite capable of standing up to continuous A.D. tapping and that the change to A.B.C. is unnecessary and therefore, owing to the loss of crop, uneconomic.

The danger of assuming that results obtained from A.D. tapping in this experiment are of universal application cannot, however, be emphasised too strongly. The conditions on this estate are exceptionally good, and equally favourable results must not be expected under less favourable conditions.

There is no universal tapping system that will give the best results under all conditions. All that can be done so far as tapping systems are concerned, is to choose the one most suited to the particular conditions encountered.

Under many conditions it can be shown that introducing periods of rest into a tapping system produces an improvement. It must not however be assumed that the improvement brought about by resting the trees is the best that can be made. By changing the tapping system one is endeavouring to adapt the treatment of the trees to their environment. There always remains the possibility of changing the environment by cultivation, using the word in its widest sense, and by so doing to effect sufficient improvement in the trees to enable them to stand up to a heavier tapping system without ill effects.

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Kuala Lumpur
17th September, 1937

NOTE
ON THE INTRODUCTION OF NEW CLONES FOR USE ON ESTATES

The following circular, which has been issued from the Botanical Division, is reprinted for general information.

The Rubber Research Institute has recently received a number of enquiries regarding the value of new clones that, as judged on the results of early tapping tests, show great promise. Estates on which it is intended to carry out an extensive replanting programme over a period of years are debating the advisability of purchasing small quantities of budwood of these new clones for multiplication for future use.

We do not consider that the value of a new clone can be assessed with sufficient certainty until the first buddings of the clone are at least ten years old and have been tested under a normal tapping system for not less than five years. High initial yield must be regarded as a starting point in the selection of new clones. From this point it is necessary to obtain a great deal of additional information before a clone should be considered for use in commercial planting. Any new clone must reach a high standard in order to supersede the best of the older proved clones at present available. The standard of selection of new clones is likely to become increasingly rigid as further knowledge of the older clones is gained from large areas which are now being brought into production.

A new clone must be required to show, in addition to high yield, during the early tapping years;

(a) satisfactory rate of increase in yield,
(b) good bark characters in both the primary and the renewed bark,
(c) mechanical strength of the tree, *e.g.* resistance to storm damage,
(d) resistance to disease, *e.g.* brown bast and leaf diseases.

It is also desirable to know as much as possible concerning the quality of the latex, *e.g.* tendency towards lumping and premature coagulation in the field, rate and duration of flow at tapping, as these may be important considerations in practice on the commercial plantation.

It is clear that a considerable period of careful test and close study is required in order to supply these data. Having obtained the detailed information required from the original group of

buddings it will still be very desirable to discover how environmental conditions, particularly soil conditions, are likely to influence development and yield.

Experience gained from the earliest clones has amply demonstrated the importance of soil conditions in their effect on growth and yield. Certain clones of which the first series of buddings gave excellent results under the conditions of test, have failed to reach the same high standard under other conditions on different soils. Some of the older clones have been shown to be satisfactory under a wide range of different conditions and these are likely to be chosen in preference to new clones that have been less well-tried even though their early records may be very satisfactory.

The Introduction of New Clones for Commercial Planting

Valuable time may be saved in the introduction of promising new clones in commercial practice by the adoption of one or other of the methods outlined below.

(1) As soon as a first selection of new clones has been made in experimental plantings on the basis of a short period of test-tapping, a small number of buddings of the most promising clones may be planted in trial-plots on a wide range of soils. In these trial-plots the new clones may be interplanted with buddings of one of the best of the older clones both for comparison and so that, in the event of failure of a new clone, an economic stand of satisfactory trees will remain. Such trial-plots will give valuable information on the suitability of the new clones for different conditions whilst further evidence of their value is being obtained from the continuation of the tests on the original groups of trees. When the original series of buddings have been under test for the requisite minimum period of five years the young buddings in the trial-plots will be approaching tappable age. By this time the records available will have revealed the most satisfactory clones of the first selection. From the trial-plots it will be possible to judge whether these clones are likely to prove satisfactory under a wide range of conditions. A clone which is shown to be of outstanding value in the original tests and has made satisfactory growth in a trial-plot in comparison with the 'control' clone may now be multiplied for further planting. Tapping tests in the trial-plots will give valuable additional information for further selection of new clones most suited to different conditions.

(2) It is certain that a group of clones selected on the basis of a short period of tapping and the limited observations of secondary characters possible on young trees, will contain a large

number of clones that will have to be discarded before the minimum period of five years test has elapsed. If the course outlined in (1) above is followed therefore, considerable expense may be incurred in testing material which proves of little ultimate value. An alternative is to wait until the tests on the original trees have been in progress for two to three years and then to establish trial-plots of the best clones of the first selection. Although trees of the best clones would be less advanced in growth at the time when the original trees reached the end of the five-year test-period they would probably be sufficiently developed to give a fair indication of the general vigour and suitability of a particular clone for local conditions and would also provide sufficient material for further rapid multiplication of budwood.

(3) To purchase budwood of very young clones for multiplication only is likely to be expensive and wasteful. It has already been pointed out that a provisional selection of clones made at a very early stage of test is likely to be subject to frequent revision before a final selection can be made. If, therefore, it is not intended to establish trial-plots, multiplication of material could be delayed with advantage until elimination of less-promising clones is further advanced. At a conservative estimate, reckoning on a ten-fold increase at each multiplication, it is possible from one yard of budwood to prepare sufficient budwood for an area of about 600 acres in four years, so that it is clear that such work can well be delayed until the new clones have been under test for at least three years.

Recommendations

Of the three courses discussed above for the introduction of promising new clones we consider that the course outlined in (2) is probably the most satisfactory. New clones selected on the results of short periods of test-tapping should be planted in small trial-plots together with one or more of the best of the old proved clones for comparison. By this means valuable first-hand information on the new clones will be obtained and at the same time nucleus material will be established from which rapid multiplication can be made at any future time. Trial-plots of $\frac{1}{4}$ to $\frac{1}{2}$ acre for each clone, planted at a density of 180 to 200 trees per acre, half of the trees being buddings of an older clone known to be satisfactory under local conditions, would be suitable.

Kuala Lumpur,
19th June, 1937

C. E. T. Mann
Head of Botanical Division

REPORT ON A VISIT TO MALAYA, JAVA AND SUMATRA*

BY

R. K. S. Murray, A.R.C.Sc.

Botanist and Mycologist, Rubber Research Scheme (Ceylon)

This report, published in May, 1937, contains much of interest to rubber growers in Malaya. Extensive extracts from it are therefore given below.

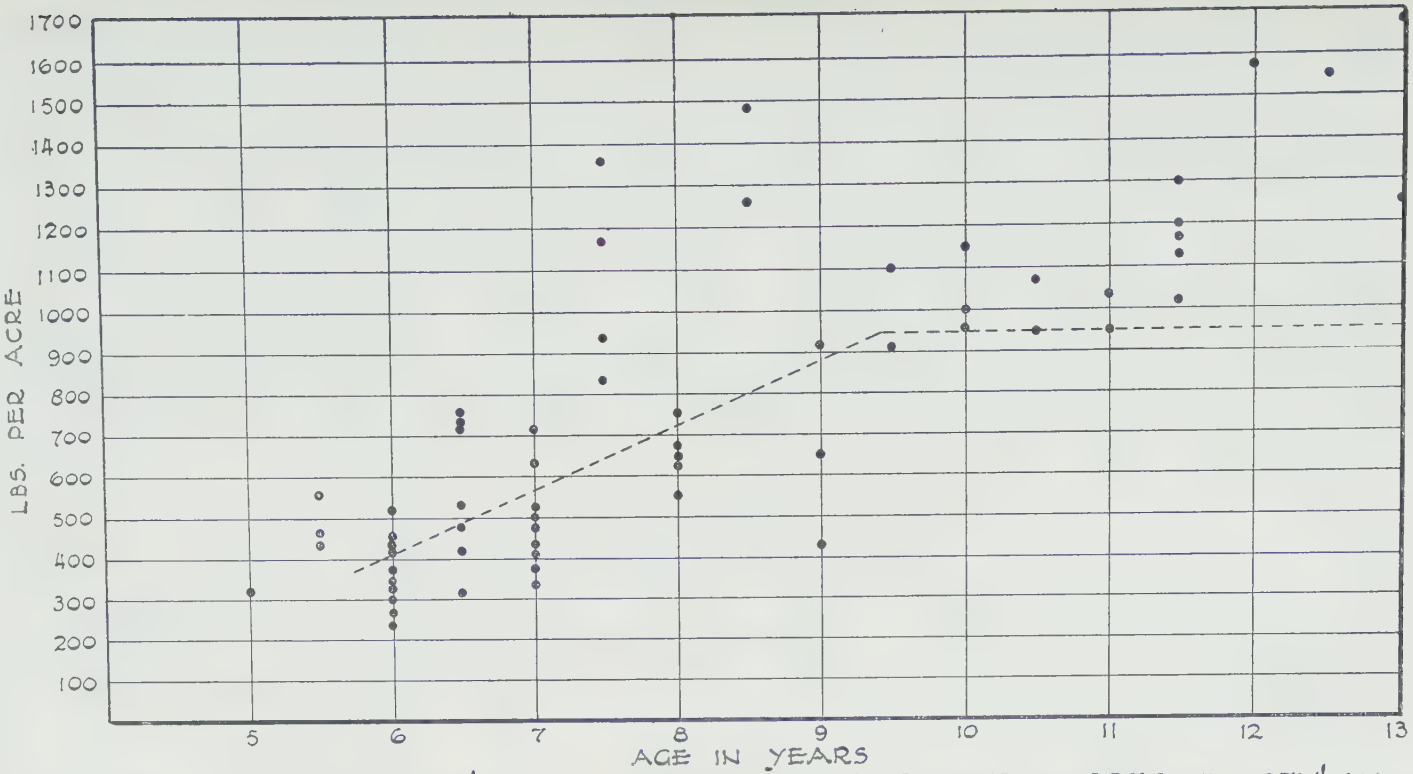
"The tour covered by this Report was the outcome of a "suggestion made by the Ceylon Association in London that an "officer of the Rubber Research Scheme should visit Malaya and "the Netherlands East Indies with the object of acquiring first-"hand information regarding the yields of budgrafted Rubber in "commercial practice. While this remained the main purpose of "the tour, the opportunity was also taken of studying the general "agricultural conditions and practices on Rubber estates in the "three countries visited.

Budgrafts

"During the course of my tour I inspected as many budded "areas in commercial tapping as possible, and the yield figures "from these and other estates are given in Table I. The total area "represented by these figures is 9,530 acres, though some of the "records are derived from test blocks comprising portions of very "much larger areas. Five acres has been taken as the minimum "size for "practical" records. It will be noted that some of the "areas referred to consist of mixed plantings of buddings and "seedlings. These figures are included as they comprise some of "the oldest and largest blocks, and the stand usually contains more "buddings than seedlings.

"The figures are also plotted in the accompanying graph, each "dot representing a recorded yield in lbs. of dry rubber per acre "per annum. The graph shows better than any words the trend "of the yields at the different ages. For comparison with the yields "actually obtained, the scale of assessment adopted by the Budded "Rubber Assessment Board in Ceylon is shown by the dotted line. "Since the yields represented in the graph are derived from a great "variety of clones, some proved and others unproved, the assessment

* Published as *Bulletin* no. 54 of the Rubber Research Scheme (Ceylon)



------ OFFICIAL SCALE OF ASSESSMENT OF BUDDED RUBBER IN CEYLON (AVERAGE OF ALL CLASSES OF CLONES) AT 100 TREES PER ACRE

TABLE I

Yield records of areas planted with buddings or mixed buddings and seedlings in commercial tapping.

Country	Acres	Planting Material	Tapping system	Yield in lbs. dry rubber per acre per annum at ages of (years)																
				5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13
Malaya	20	Mixed Clones	½ sp.a.d.	...	...	...	...	*720	...	...				...	...	...	...	...	...	
	1,300	Mixed buddings and seedlings	do	...	...	...	...	...	...	...	...	432	...	...	...	...	...	...	...	A
	650	(A.V.R.O.S. 49	do	...	...	...	420	...	...	...	...	...	...	...	...	...	...	...	...	
		(A.V.R.O.S. 50	do	...	...	...	484	...	...	...	...	...	...	...	...	...	...	...	...	
	60	A.V.R.O.S. 49	do	...	...	517	...	...	...	...	...	...	...	...	...	...	...	...	...	
	60	A.V.R.O.S. 50	do	...	...	464	...	...	...	...	...	...	...	...	...	...	...	...	...	B
	60	A.V.R.O.S. 152	do	...	...	393	...	...	...	...	...	...	...	...	...	...	...	...	...	
	60	P.B. 25	do	...	578	...	757	...	937	...	...	...	...	...	...	...	...	...	...	
	60	S.R. 9	do	...	...	...	324	...	...	...	...	...	...	...	...	...	...	...	...	
	532	Mixed Unproved	do	...	...	...	...	...	...	...	...	...	...	...	...	960	...	...	...	
	278	do	do	...	...	...	...	...	...	...	...	...	...	...	960	...	...	...	...	
	405	do+seedlings	do	...	...	...	...	...	...	...	...	...	...	...	...	...	*1181	...	...	
	355	do	do	...	...	...	...	...	...	...	...	...	...	...	...	...	*1018	...	...	C
	258	do	do	...	...	...	...	...	...	...	...	...	...	...	*1073	...	...	...	...	
Sumatra	2,667	Mixed seedling	½ sp.d.a.m.	...	...	...	...	...	...	...	...	...	...	975	...	...	...	...	...	
	190	Mixed unproved	do	...	...	...	...	...	...	...	...	...	...	1000	...	...	...	1570	...	1670D
	5½	do	do	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1540	
	9½	do	do	...	...	...	...	...	...	...	...	...	...	...	...	...	1300	...	...	
	13¼	do	do	...	...	...	...	...	...	...	...	...	...	...	...	...	1150	...	...	
	13¼	do	do	...	...	...	...	...	...	...	...	...	...	...	...	...	1200	...	...	1248E
	1,000	do	do	...	...	...	...	...	...	...	...	...	...	...	...	*1050	...	...	...	
	20	(A.V.R.O.S. 49	do	...	447	...	740	...	1185	...	1264	...	...	...	...	...	...	...	...	
		(A.V.R.O.S. 152	do	...	466	...	722	...	1368	...	1498	...	...	...	...	...	...	...	...	
	7	Mainly A.V.R.O.S. 49	do	...	...	...	...	...	...	...	...	...	*1100	...	...	...	...	...	...	
Java	55	B.D. 2, 5, 10	½ sp.3.d.	326	...	472	...	640	...	670	...	...	...	...	...	...	...	...	...	
	300	do	do	...	...	300	...	458	...	550	...	...	...	...	...	...	...	...	...	
	178	do	do	...	...	282	...	403	...	...	...	...	...	...	...	...	...	...	...	F
	185	do+B.D. 16, 17	do	...	...	335	...	500	...	653	...	...	...	...	...	...	...	...	...	
	367	do	do	...	...	272	...	392	...	...	...	...	...	...	...	...	...	...	...	
	500	Mostly T.J. 1	⅓ sp. d.a.m.	...	...	446	...	...	...	...	...	...	...	...	...	...	...	...	...	
	16	Cultuurtuin clones	do	...	...	...	...	497	...	680	...	937	...	*1160	...	...	...	...	...	
	24	Mixed A.V.R.O.S. clones	do	...	...	367	...	527	...	737	...	*665	...	...	...	...	...	...	...	G
	300	Mixed clones (50% T.J. 1)	do	...	...	...	*535	...	...	...	...	...	...	...	...	...	...	...	...	
	90	Mixed proved and unproved	do	...	...	273	...	358	...	...	...	...	...	...	...	...	...	...	...	
	60	W.R. 24	½ sp.a.d.	...	...	...	...	...	*845	...	...	...	...	...	...	...	...	...	..	
	31½	Mixed unproved clones	do	...	...	...	...	...	...	...	...	...	*906	...	...	...	...	...	...	

Tapping Systems.

½ sp.a.d. = ½ spiral alternate daily.
½ sp.3.d. = ½ spiral third daily.
½ sp.d.a.m. = ½ spiral daily, resting in alternate months.

* Signifies that the figure is calculated from the yields for an incomplete year (1936). Except where otherwise stated under Remarks the calculation is based on at least 9 months' tapping.

Remarks.

A. Calculated from 1 month's figures only. Age varies from 8½—9½ years.
B. Representative of much larger blocks.
C. Calculated from 5 months' figures only.
D. Yield has since decreased with cessation of manuring.
E. Heavily supplied with much younger plants.
F. Very wide planting and rather poor soil. B.D. 2 tapped on 1/3 sp.3.d.
G. Rather poor soil.

" figures have been taken as the averages for all classes of clones. " The assessments are based on a standard system of alternate " daily tapping on a half-spiral cut, whereas reference to the Table " will show that many of the lower yields are derived from a milder " system.

" If these "practical" figures are compared with the well-known " records derived from the test-tapping of experimental plots it is " found that the two series follow a very similar trend, with the " " practical " figures somewhat lower. This is in accordance with " expectations since the areas in commercial tapping are mostly " planted with the older clones of more moderate merit. Indeed " many of the figures in Table I are derived from clones which were " quite untested at the time of planting, and the extremely satis- " factory performance from most of these areas is rather surprising. " The reader may draw his own inference from these records, but " perhaps it should be added that there has been no conscious " selection on my part in presenting them. I have given *all* the " records from commercial tapping which came to my notice during " the course of the tour. If there are any instances of entirely " unsatisfactory results from budded areas I did not come across " them.

" These results show beyond the possibility of doubt that " yields greatly in excess of those to be expected from unselected " seedling material at similar ages are being obtained in estate " practice, and it is almost certain that appreciably larger yields " will be obtained from younger clearings which are planted with " better clones. It now remains to examine the alleged defects " of budgrafts, on which the fears that these high yields will not be " maintained are based.

" **Bark Renewal.**—Of all the doubts which have been expressed " regarding the value of the budgrafted tree as a form of planting " material, bark renewal probably accounts for the most numer- " ous. The virgin bark of a budgraft has a similar exterior " appearance to that of a branch, and it is commonly averred that " " branch bark " will not renew. This is possibly the most " formidable contention with which the protagonist of budding has " to deal, for it is based not entirely on abstract argument—as are " so many of the alleged defects of buddings—but partly on ob- " served fact. It is true that the bark renewal in some of the older " budded areas is unsatisfactory, not so much on the score of thick- " ness but because irregularities have developed on the renewed " panels. What is not universally realised is that bark renewal, " like yield and other secondary characteristics, is a function of " the clone and not of the budgraft as such. The older areas were

" planted with clones on which no, or insufficient, observations had " been made in respect of secondary characteristics, and many of " these clones have subsequently been found to be unsatisfactory " as regards renewal. These defective clones have for some years " been discarded, and no clone is now recommended which has not " been proved to be satisfactory in this respect. For a new clone " 5 years tapping is usually regarded as the minimum period before " that clone can be recommended for commercial planting, but for " all the older clones which are now being extensively used for " replanting the tapping history is much longer.

(Reference is then made to the lecture given by Mr. C. E. T. Mann, Senior Botanist of this Institute, at the 1936 Annual Conference of the Incorporated Society of Planters)*.

" I was able to make numerous observations and rough " measurements of renewed bark in budded areas, and on all " approved clones the first renewal was entirely satisfactory. Ac- " curate measurements made by the Rubber Research Institute of " Malaya in blocks in commercial tapping have shown that after " 12 months the thickness of the renewed bark is between 60 per " cent and 70 per cent. of that of the virgin bark. Observations on " second renewal were obviously confined to the older areas which, " as mentioned above, are planted with largely untested material. " Here the second renewal was somewhat variable, and I formed " the impression that regeneration was rather slower. This, how- " ever, is usually the case with any type of planting material.

" Evidence that satisfactory yields are obtained from the " tapping of renewed bark are not lacking.

(Here further reference is made to the above-quoted paper by Mr. C. E. T. Mann)..

" All the clones now recommended for planting have been " tapped on renewed bark, and in almost—if not quite—every " instance the yield on the renewed bark was relatively higher than " on virgin bark at the same height.

" Most of the older areas in Sumatra, for which the figures " are given in Table I, are now being tapped on first renewal with " satisfactory results. Tapping of second renewal was also seen " on two estates, one in Sumatra and one in Java.

Plates are reproduced (in the original) to illustrate the appearance of renewed bark on buddings of approved clones.

" **Maintenance of Yield.**—Another of the " bogies " of budgraft- " ing is that the high yields secured when the trees are young will

* See this *Journal*, **8**, 1937.

" not be maintained into full maturity. The maintenance of yield " is, of course, largely connected with bark renewal, but there also " seems to be a fear that the budded trees, being an unnatural " product, will be shorter-lived than the seedling. The useful " economic life of a budding is a matter that can only be determined " by future experience, and, as with seedlings, it will depend on " how the tree is treated. At present we can only say that there " does not seem to be much cause for anxiety. The original trees " of the oldest clones are now in their 19th year, and although in " most cases the yields are no longer on the increase they are being " well maintained. For example, the average yield of the original " 7 buddings of B.D.5 was 31.7 lbs. per tree in the 19th year (on " renewed panels).

" The original trees of Tjirandji 1, of which only 2 remain, " were reported to have given a very high yield in 1936 but the " figures cannot be quoted as they are subject to verification by " the Proefstation.

" How budgrafts will behave when they are 30 or 40 years " old we do not know, but it is fairly certain, that at this age the " best of the clones at present in use will have been excelled by " newer clones and families or seedlings of known parentage which " are now being studied, and it will pay to replant with more " modern material.

" **Growth on Different Soils.**—There is a current belief that " budgrafts will show satisfactory development and yields on certain " types of soil but not on others. This is a half truth. Susceptibi- " lity to soil conditions is a characteristic of the individual clone " and not of the budgraft. Any reaction to environment is more " markedly evident in a mono-clone block of buddings than in a " mixed stand of seedlings because every tree in the former, being " of genetically identical origin to its neighbour, will react in the " same way. Some clones are much more susceptible to soil con- " ditions than others, and before an estate commits itself to exten- " sive planting of any particular clone it is obviously important to " know how that clone is likely to fare under the local conditions. " Information regarding the regional suitability of clones is by no " means complete but is becoming available fairly rapidly, some- " times, it must be admitted, as the result of unhappy experience. " Fortunately the Rubber soils of Ceylon show much less variation " in type than those in Malaya, and a clone which is shown to grow " well in, for example, the Kalutara District will probably do well, " also, in the Kelani Valley. A soil on which none of the best " proved clones will grow, even with the help of manure, would be " too infertile to support any type of Hevea.

"**Brown Bast.**—Of the older objections to buddings such as "weakness at the union, susceptibility to disease etc. little need be "said except that they are mostly quite unfounded. Certain clones "are more liable to contract certain diseases than the "average seedling, but the only important malady for which there "are varietal differences is Brown Bast. The incidence of this "disease, being closely related to latex extraction, is nearly always "greater with high than with low-yielding material whether that "material is budded or otherwise. Certain clones are markedly "susceptible to Brown Bast and these have been excluded from "the recommended lists, but for all high-yielding clones the "incidence can be greatly reduced by adoption of a suitable tapping "system. Very satisfactory yields are being obtained on clones "liable to Brown Bast by tapping on one-third, or sometimes only "one-quarter of the circumference.

"In areas budded with mixed clones it is more convenient to "shorten the tapping cut than to lengthen the interval between "tappings but it is debatable which is the more effective method "of combating the tendency to the disease.

Seedlings

"The collection of seed from known high-yielding trees was "the earliest step in seed selection, and general experience has "shown that such progeny usually gives appreciably higher yields "than ordinary unselected seedlings. The only yield figure obtained "from this class of material during the tour was one of 860 lbs. "per acre at 12 years old, compared with 1,073 lbs. per acre from a "neighbouring block (258 acres) of mixed unproved buddings and "selected seedlings 18 months younger.

"The testing of ("clonal") seedlings has engaged the atten- "tion of the research organisations in Malaya, Java and Sumatra "for some years, and the general conclusion reached is that at this "stage of the genetical study the outcome of any particular cross "cannot be predicted with certainty from the characteristics of the "parent or parents. A clone whose buddings show vigorous "growth and a high yield may or may not give seedling progeny "with the same characteristics. Instances of this apparent paradox "will be given below, but the point I wish to make at this juncture "is that a good bud-parent is not necessarily a good seed-parent, "and it is therefore inadvisable to plant illegitimate seed of Clone X "until something is known of Clone X as a mother parent. The "testing of seedling families presents a problem rather similar to "the testing of budgrafted families (clones). It is now generally "known that the budded progeny of a high-yielding seedling tree

"does not always reproduce that high yield—at least in the early "years—and that every clone has to be tested for a period of years "before it can be approved. In the same way the seedlings result- "ing from a particular cross must be tested before they can be "approved. Having established this point we may now see how "far such work has progressed.

"The earliest studies on the inheritance of high yield in "seedlings resulting from the artificial crossing of selected parents "were carried out by Heusser at the A.V.R.O.S. Proefstation, "Sumatra. The parents used were high-yielding seedling trees "on estates. It was found that, as a whole, such material gave "yields greatly in excess of the ordinary unselected seedlings used "as controls, and that certain families had an outstandingly good "performance. The same parents were used for the establishment "of clones, but the parents which gave the best clones did not "always give the best seedlings. For instance, the mother-trees "of Clones A.V.R.O.S. 49 and 50, which are well known as two "of the best of the older A.V.R.O.S. clones, gave seedlings of only "moderate merit, while A.V.R.O.S. 157, which was discarded as a "clone at an early stage of testing, gave an extremely high-yielding "group of families.

"Table IV reproduces the yield records from all the crosses "from the 157 family group and from the control unselected "seedlings.

TABLE IV

Material	Yield in lbs. per tree per annum at ages of					
	4½	5½	6½	7½	8½	9½
Unselected Seedlings	1.1	3.0	2.7	4.2	5.9	4.7
All Crosses ...	2.0	5.9	6.7	9.4	11.7	11.3
157 Family Group ...	3.5	9.5	10.0	13.8	17.7	14.6

"These records show that the seedlings resulting from the "careful crossing of selected high-yielding parents (but not proved "as parents) give yields more than double those of unselected "seedlings, and that the best family group gives yields comparable "with buddings of first-class clones.

"These studies have been continued in Sumatra, crosses being "made between various clones and between individual seedlings "resulting from the earlier pollinations, and parents which give "promise of excelling 157 are being disclosed. Illegitimate seed- "lings from most of the A.V.R.O.S. clones are also being test- "tapped and some of these are giving very high yields. As the "outcome of these results the A.V.R.O.S. Proefstation is now "suggesting that up to 20 per cent. of any replanted area be planted "with illegitimate seedlings collected from buddings of the under- "mentioned clones, provided that areas from which seed is taken "are planted entirely with budgrafts of these and other good clones "and do not include seedling plants.

"A.V.R.O.S. 35, 80, 152, 161, 163, 166, 185, 214, 274, 278, 282, "284.

"It is recognised, however, that the results from such material "are less certain than those obtainable with buddings of proved "clones.

"Most of the breeding work in Malaya has been carried out "by the R.R.I. on the Pilmoor clones, and on Prang Besar Estate "with their own clones.

(Reference is then made to the paper by Mr. C. E. T. Mann in this *Journal 7*, (1936), 102).

"Results from Prang Besar Estate confirm the high promise "of legitimate seedling families.

"Seed from isolated gardens planted with the same Prang "Besar clones is now being extensively used for replanting in "Malaya, but the results with the Pilmoor clones indicate that "this illegitimate material is unlikely to give as high yields as "those from Plots P1 and P2 (See Circular issued by the Prang "Besar Rubber Estate, Ltd. in 1936) where the seedlings have "resulted from controlled crossing.

"Some very interesting crosses between the Bodjong Datar "and Tjirandji clones are now being tapped on the Experiment "Station, Tjiomas, of the Proefstation West Java, and figures are "reproduced from a recent paper by Ir. J. S. Vollema, Agricultural "Officer of the Proefstation, in *De Bergcultures*" X, 42, p. 1292.

"The "selfed" seedlings of Tjirandji 1 and the crosses between "Tjirandji 1 and Tjirandji 16 are seen to be of outstanding promise. "The latter, however, have shown a marked susceptibility to Brown "Bast and wind damage. B.D.2 is promising as a male parent, "and it is interesting to record that the susceptibility to Brown "Bast displayed by the buddings has not been reproduced in the "seedlings resulting from pollination by this clone. Photographs

" of the Tjirandji 1 " selfed " seedlings and the Tjirandji 16 × 1 " crosses are given.

" All the records of legitimate and illegitimate seedlings given " (in the report) are derived from the test-tapping of relatively " small groups of trees, often for only a short period. The situation " as regards the confirmation of these results by commercial tapping " of large areas in estate practice is similar to that for budding " some years ago. In the course of my tour I was able to collect " only one series of figures of a " practical " nature. These are of " considerable interest and are reproduced in Table VIII. The seed " was derived from an isolated garden planted with buddings of " high-yielding estate trees. The tapping system was half-spiral " alternate daily.

TABLE VIII

Acres	Planting Distances	Yields in lbs. per acre at years of $5\frac{1}{2}$	$6\frac{1}{2}$	$7\frac{1}{2}$	$8\frac{1}{2}$	$9\frac{1}{2}$
98	18′ x 18′ △	...	274	496	545	879
10	12′ x 24′	...	328	519	502	...
31	18′ x 18′	...	417	672	828	915
5	16′ x 16′ △	...	690	1012	...	...
18	16′ x 18′	429	670	743	906	...
9	16′ x 16′ △	621	727	830	...	...
16	16′ x 16′ △	...	553	819	...	...

" When comparing these figures with those given in Table I, " note should be taken of the planting distances which are much " closer than those in most of the budded areas. It should also be " recorded that the general level of yield in the locality is high.

" Sufficient data have now been adduced to enable a summary " of the evidence regarding the value of the so-called " clonal " " seed to be made. The results from the legitimate seedling " families show that such material in the early years has poten- " tialities for yield similar to buddings of what may be termed good " average clones, the best families being more or less on a par " with the highest-yielding clones. At the present time, however,

"seed of this class is not, in general, commercially available as it "can only result either from artificial pollination or from a mixed "plantation of two clones planted in such a way that fertilisation "from outside sources is unlikely to occur. (In the latter event an "appreciable proportion of the seed might be "selfed"). This "statement should be qualified by saying that an enterprising "proprietor in Java has recently made a very large number of "artificial pollinations between Clones Tjirandji 1 and 16 and is "selling the seed commercially, but, in general, the statement that ""proved" legitimate seed is not at present available for planting "holds good.

"A special case of legitimate seed is "selfed" seed *i.e.*, where "both parents are of the same clone. Seed of this nature can be "collected from a monoclone block, either planted in an isolated "position or of such a size that the chances of outside pollen reach- "ing and fertilising the trees in the centre of the block is remote. "The figures given in Table VII (not reproduced here) show that "very high yields have been obtained from "selfed" seedlings of "Tjirandji 1 in the first two years of tapping, but here again all "clones do not respond to "selfing" in an equally satisfactory "manner. For example, Clones Tjirandji 1 and A.V.R.O.S. 33 give "vigorous and high-yielding "selfed" seed, whereas the "selfed" "seedlings of A.V.R.O.S. 49, A.V.R.O.S. 50 and S.R. 9 show "extremely unsatisfactory growth. At this stage, therefore, it "would be most unwise to plant seed collected from a large mono- "clone block unless the clone in question has been proved to give "satisfactory "selfed" progeny.

"The class of seed which could be collected in considerable "quantities from the older budded areas in Ceylon is illegitimate "seed of which only the female parent is known. Experimental "work has shown that in general such material is inferior to "buddings of the best clones, but certain clones are known which "appear to give high-yielding seedlings irrespective of the source "of the pollen. Such clones are A.V.R.O.S. 157, A.V.R.O.S. "163 Pilmoor A.44 and possibly Tjirandji 1. The evidence regard- "ing the value of these clones as mother parent is still very "incomplete as the tapping records are mostly of short duration, "but if it could be shown that buddings of a particular clone carried "a dominant character for high yield (associated with desirable "secondary characteristics) the seed from those buddings would "be of commercial value comparable with the best budgrafts. "It appears from the evidence available that we have not yet "reached that stage.

"It has been suggested that the yield of a plantation of "illegitimate seedlings could be raised to the level of the best

" clones by adopting a high initial density of planting and thinning " out the poorer trees on early tapping tests. This procedure would " make use of the fact that the variability amongst individual trees " is greater with seedlings than with buddings, but it must not be " overlooked that an appreciable degree of selection can also be " made with the latter. The extent to which yields could be raised " by this means has recently been examined by the Rubber Research " Institute of Malaya, working with records from illegitimate " seedlings of Clone Pilmoor A.44 and buddings of A.44, Tjirandji 1 " and P.B.186. It has been found that by elimination of the poorest " one-third the average yield of the seedlings is raised by about " 20 per cent. and of the buddings about 14 per cent. By eliminating " the poorest half the figures are about 30 per cent. and 20 per cent. " respectively. Even with the lowest yielding half removed the " average yield per tree of the seedlings is lower than that of the " buddings. With illegitimate seedlings of a more average clonal " parent the disparity, of course, would be greater. Moreover, it " must be borne in mind that in practice the removal of the lowest " yielders could not be carried out strictly as consideration must be " given to position as well as to yield.

" Attention has so far been devoted purely to the question of " yield, but secondary characteristics are no less important with " seedlings than with buddings. Observations on the secondary " characteristics of legitimate seedling families are necessarily less " extensive than on the older clones, but it has already been found " that sometimes the undesirable characteristics of the parent clones " are displayed in the seedlings. Thus, the seedlings derived from " A.44 as a mother are showing the irregularities on the renewed " panels characteristic of the clone, and it is possible that despite " the high yields this clone will have to be discarded as a female " parent. As an illustration of the uncertainties of genetical work " with Hevea, this inheritance of bark characteristics may be " contrasted with the experience in Sumatra with A.V.R.O.S. 185. " This is a very high-yielding clone but the buddings are very " crooked and the bark renewal is poor. The illegitimate seedlings, " on the other hand, are not only giving promising yields but do " not reproduce these defects.

" This section may be concluded by stating that we are now " very much in the same position as regards our knowledge of " legitimate and illegitimate clonal seed as we were about eight " years ago with buddings. Replanting with any form of seedling " material at present commercially available is a much more un- " certain proposition than replanting with buddings of approved " clones.

Soils

"The visitor from Ceylon to Malaya cannot fail to be struck "by the great diversity of soil types in the peninsula. Whereas "most of the Rubber soils in Ceylon conform to one type, portions "of Malaya remind one of nothing so much as a patch-work quilt. "In general, the soils have a higher clay fraction than in Ceylon.

"The coastal clays and peats are quite unlike any Ceylon soils. "They are rich in nitrogen and organic matter, and the best clays "are also relatively well provided with phosphate and potash. The "yields, however, are rather disappointing in relation to the general "appearance and foliage. Speaking very generally, it would pro- "bably be true to say that the worst Malayan soils are more "sterile than anything we have in Ceylon, but the best soils are "intrinsically richer. The growth and bark conditions, of course, "conform closely to the state of the soil.

"The soils seen in the East Coast District of Sumatra are of "two types. There is a stiff white coastal clay on which early "growth is rapid but subsequent deterioration equally rapid in the "absence of cultivation, and a red volcanic loam of looser texture "which overlies the clay. Rubber trees on the white clay res- "pond very rapidly to nitrogenous manuring, and the most "striking example of successful manuring seen on the tour was "on the H. A. P. M. group of estates, where the average yield has "been raised to about 680 lbs. per acre by regular applications of "sulphate of ammonia for a period of about ten years. The red "soils grow excellent Rubber, and the response to manure is either "slower or absent.

"The only part of Java visited was West Java, and except for "limited areas of a whitish clay the only soil seen on Rubber "estates was a red volcanic loam of great depth. Except where "the land has been cultivated for many generations and mineral "deficiencies are shown, the growth of the trees is excellent and "manuring appears to be unnecessary.

Manuring

"Until quite recently the application of artificial manures to "either mature or immature trees was an almost unknown "practice in Malaya. The bulk of experimental evidence shows "that sulphate of ammonia is as effective a source of nitrogen "as the more costly organic manures. Reference has already been "made to the striking results obtained by regular applications of "nitrogen on the white clay soils of Sumatra. Applications of "phosphate and potash to mature trees have given negative "results, and there is indeed, some evidence that phosphorus in

" the form of super-phosphate depresses yields in the presence of " nitrogen and absence of potash. It certainly results in lower " dry rubber contents. Nitrogen manuring on the red soils of " Sumatra has, as a rule, not much effect if the land is under " cover crops. Phosphate manuring in combination with cover " crops such as Pueraria and Centrosema has resulted in a marked " improvement of the trees and a marked increase in yield. " Manuring with rock phosphate in quantities varying from 200 " to 400 lbs. is more and more becoming standard practice on these " soils.

" The red volcanic soils of West Java only appear to need " fertilisers where the land has been under prolonged cultivation. " In such cases applications of phosphate and potash may be " beneficial. A marked response to nitrogen was seen in an area " of mature Rubber on a poor whitish clay.

Cover Crops

" **Leguminous Covers.**—Whereas in the Netherlands East Indies " there is hardly a square yard of soil under mature or immature " Rubber which does not carry a ground cover of either *Pueraria* " *phaseoloides* or *Centrosema pubescens*, in Malaya the establishment " of creeping legumes in old Rubber is a matter of the utmost " difficulty. The present tendency is to encourage an under- " growth of naturally occurring species most of which, of course, " are not legumes.

" A species of *Desmodium* indigenous to Malaya, *D. ovalifolium*, " has recently been discovered which gives promise of forming " a satisfactory cover under heavy shade. The habit is semi-erect " and rather similar to, but denser than, *Desmodium heterocarpum*, " which is well known in Ceylon. While in Java I saw two other " leguminous species which tolerate shade, at least on certain soils: " *Psophocarpus palustris*, which is a creeper rather resembling " *Calopogonium* in appearance, and *Aeschynomene Americana*, an " upright type which dies off in dry weather and re-sows itself.

" **Natural or " Forestry " Covers.**—The idea of encouraging a " growth of indigenous species in mature areas arose in Malaya " from the failure to establish legumes. The so-called " forestry " " cover is entirely a product of Malaya and does not appear to " have aroused much interest in the Netherlands Indies. It was " largely the outcome of the period of economic depression when " weeding costs had to be reduced to a minimum and the " forestry " movement " must have proved attractive to many companies on " this account. The proportion of estates on which natural " covers are growing is considerable but the number on which such

"methods have yet improved the condition of the Rubber appears "to be very limited.

"I was privileged to spend an extremely interesting morning "on an estate on which the introduction of natural covers was "started in 1929 and on which an excellent and well controlled "cover has been obtained throughout. Although no portion of the "estate has been kept clean weeded as a "control," it was evident "that the cover has been of great benefit both to the soil and the "trees. It appeared, however, that the work had been carried out "under favourable conditions in three respects:—

"(1) The soil in the locality is a granite loam of more than "average intrinsic fertility.

"(2) The estate is bordered by a large block of jungle from "which seeds could be carried by birds.

"(3) The superintendent had clearly devoted a considerable "amount of study to the natural flora and the correct way to "deal with it. In my consideration the personal factor is not the "least important of the tree.

"The experience on this estate can leave no doubt in the "mind of an unbiassed observer that where the correct type of "cover can be grown and proper control is exercised the soil is "restored to a condition of fertility akin to that in the natural "forest. The difficulty is that where soil improvement is most "needed it is the light-loving, strongly competitive species, such "as bracken and grasses that made the first appearance. The "replacement of these species by better types is often a very slow "process, and for the first few years the trees suffer from the "competition. With rubber again at a remunerative price it "would usually be an economic proposition to accelerate the "process by artificial manuring. The manure would lead to "increased shade and thus discourage the undesirable light-loving "growths. I formed the opinion that in many exceedingly poor "areas too much confidence was placed in the beneficial effects of "natural covers alone, the restorative action of which must be, "at its best, exceedingly slow on such land.

"On the estate referred to above the superintendent reckons "that despite keeping clean weeded strips about 6 ft. wide down "the rows of trees the cuts take from half-an-hour to an hour "longer to dry after rain than if the ground were clean weeded. "This delay in drying might be an important factor during "monsoon conditions in Ceylon, and it would probably be neces- "sary to maintain clean strips of greater width. This would "mean that a large proportion of the ground was, in effect, clean "weeded, whereas a ground cover can be allowed to grow closer "to the trees. The claims made by the extreme protagonists

" of " forestry " methods that the incidence of Oidium leaf disease " is reduced appear, as might be imagined, to be entirely unfounded.

Diseases

" **Root Diseases.**—The loss caused by root disease in Malaya " appears to be far greater than in Ceylon. The two most im- " portant fungi are *Fomes lignosus* and *Ganoderma pseudoferreum*, " the latter sometimes being responsible for a reduction of the " stand to about 40 trees to the acre. *Fomes* is chiefly of import- " ance in young clearings. The control methods recommended by " the Rubber Research Institute do not differ in any essentials " from those recommended in Ceylon, but some estates consider " that it is not an economic proposition to spend large sums of " money on control measures in old Rubber.

" In the East Coast District of Sumatra the incidence of " *Fomes lignosus* is extremely high, and on one large group of " estates the total area of vacant root disease patches must " amount to many hundred acres. In this particular instance no " control measures whatever are undertaken, the authorities " deeming treatment uneconomic. This may have been the case " with the prices obtaining in recent years, but it would seem that " large sums of money will have to be expended if such land is " ever again to be profitable for growing Rubber.

" **Leaf Diseases.**—Oidium is the only important major leaf " disease, although young trees in certain districts of Malaya " suffer rather severely from *Helminthosporium Heveae*, mites, " thrips and sundry other insect pests. The year 1936 was marked " in Malaya by an exceptionally mild attack of Oidium during the " refoliation season, and the condition of the leaves was not quite " characteristic of an average year. In general, it is not con- " sidered economic to spend money on sulphur-dusting, but I " formed the impression that Oidium was responsible for more " damage to the foliage than is generally supposed.

" In Sumatra the incidence of Oidium is very slight, but in " Java sulphur-dusting is adopted as a standard procedure in the " more severely affected localities.

Tapping

" **System.**—In Java and Sumatra the spiral cut is almost " universal, either on half or one-third the circumference. The " most popular system in Java at present is a half-spiral cut every " third day. In Sumatra the custom is to tap daily in alternate " months.

"**Height of Cut.**—To conform with the higher rate of consumption, cuts are usually opened at a greater height than in Ceylon, and usually, also, at a greater angle. In Sumatra it is usual not to tap buddings within about 9 ins. of the union on account of the decrease in yield as the junction of stock and scion is approached, but 9 ins. is considered an unnecessarily large margin in Malaya. The margin allowed in Java is 4 to 8 inches.

"**Bark Consumption.**—In Malaya the annual consumption on alternate day tapping is 9 to 12 ins. per annum. In Java and Sumatra the average consumption appeared to approach the higher of these figures. This high rate of consumption (in relation to Ceylon practice) is partly due to a larger number of tapping days on account of less interference by rain, but it was also clear that thicker shavings are removed. It is possible that Ceylon is ultra-conservative in the matter of consumption but it is a fault on the right side. The rate of renewal on many of the older estates in Malaya does not seem to be keeping pace with consumption.

"**Tapping knives.**—Either the gouge or the Jabong (a draw-knife) is used in all three countries. The Michie-Golledge has been tried experimentally on a large group of estates in Java, but was disliked by the tappers and appeared to offer no material advantages. Tapping with either the gouge or Jabong is a quicker operation than with the Michie-Golledge, and it is possible that the only advantage of the latter is that it is easier to take thin shavings.

"**Cups.**—In the Netherlands East Indies aluminium cups appear to be almost universal. These are collected by the tappers every day and taken to the factory to be washed.

"**Standard of Work.**—In general, tapping seems to be rather deeper than in Ceylon, shallow tapping being condemned as much as, or more than, the making of wounds. The work on many Malayan estates is very rough and the presence of large numbers of tapping wounds does not seem to be viewed with much concern. My first impression was that the poor work might be connected with the types of instrument, but after seeing the excellent standard of tapping achieved on certain estates in Java and Sumatra with the same knives this is clearly not the case. The explanation may lie in the fact that much of the tapping is done on contract by non-resident Chinese, thus eliminating the personal relationship between the superintendent and his labour and leading to less efficient supervision.

Replanting

"**General Policy.**—During recent years the sentiment in "regard to replanting has been much the same in Malaya as in "Ceylon. The success of the operation has been regarded as "rather problematical, and it is only quite recently that Company "Directors have been persuaded of the ultimate advantages to be "gained by replacing obsolescent trees with improved material, "and that work on a large scale has been commenced. When "comparing Malaya with Ceylon it must be remembered that the "former country possessed about 200,000 acres of budded Rubber "before the commencement of the present Regulation Scheme.

"In the Netherlands Indies a very different policy has pre- "vailed and the fact that the Rubber tree is a depreciating asset "and must be periodically replaced appears to have been recognised "by the majority of large companies. I was unfortunately unable "to obtain any official figures for the total area for which re- "planting licences have been issued, but was everywhere informed "that most companies who could afford to do so were utilising "their allowances to the utmost. This is certainly confirmed by "the many individual instances of extensive replanting pro- "grammes which I came across during my tour in both Java and "Sumatra, and by the numerous large clearings seen in the East "Coast District of Sumatra during the flight from Medan to "Batavia.

"**Methods.**—Most of the land on which we saw replanting "operations in progress is of a very different nature to the "average rough hilly areas in this country, (Ceylon).

"In Sumatra different opinions (from those in Malaya) were "expressed regarding the efficacy of root removal in reducing the "incidence of disease, but I formed the opinion that where "such treatment had been ineffective it was on account of not "being sufficiently thorough. We saw a group of estates on "which replanting has been carried out every year from 1930 "onwards, and despite the prevalence of *Fomes* in the old stand "the loss amongst the young trees has been very small. On these "estates the practice is first to dig over the soil to a depth of 18 "ins., and then to give a second light changkolling to cover the "imperfections of the first round.

"**Cover Crops and Green Manures.**—In the Netherlands Indies "it is usual to plant a creeping cover, *Centrosema pubescens* and "*Pueraria phaseoloides* being the most popular. This is kept clear "of the young plants in the early years.

"Lopping of bush covers in replanted areas is required 2 or 3 "times a year during the first few years in order to avoid over- "shading. I saw no instances in which the loppings were being "forked into the soil.

"Planting.—Where the stand is to be budded the usual "practice in Java and Sumatra is to bud in the nursery and plant "budded stumps. The stumps are cut back to within a few "inches of the bud a week or two before planting. In Malaya "the planting of budded stumps is regarded as rather a hazardous "procedure except in coastal areas on account of the lack of a "really reliable planting season. Planting is done with seed at "stake and/or basket plants, and budding carried out about 12 "months later. There is some difference of opinion as to whether "one (or two) basket plant should be used in each hole, in which "case that plant derives all the benefit from any manure incor- "porated with the filling, or whether it is better to plant "several seed at stake with the idea of selecting the strongest. "Possibly the best procedure, is to plant initially with 4 or 5 "germinated seed per hole, thinning out to the two most vigorous "plants after six months and using basket plants for supplying "holes in which the early growth is poor.

"Planting Material.—In Malaya about 20 per cent. of the "recent clearings have been planted with illegitimate clonal seed, "mostly from the Prang Besar isolated seed gardens, and the rest "with monoclone blocks of buddings.

"A considerable amount of illegitimate clonal seed of the "parents recommended by the A.V.R.O.S. Proefstation is also "being used in Sumatra. In the main, however, the areas are "being planted with monoclone blocks of the following clones: "A.V.R.O.S. 49, B.D. 5, Tjirandji 16, Waringiana 4, P.R. (Proef- "station voor Rubber) 107, Pilmoor B. 84 and D. 65, Glenshiel 1 "and Sabrang 24.

"Most of the replanting I saw in Java was on the estates of "Anglo-Dutch Company. All clearings are being planted with "seedlings from the Company's own Tjikadoe isolated seed garden, "but some clearings have subsequently been budded. The best "Java clones at the present time appear to be Tjirandji 1 and 16, "B.D. 5, War. 4, P.R. 107, L.C.B. 1320 and W.R. 101.

"Manuring.—Except on the coastal clays it is a generally "accepted fact in Malaya that regular applications of artificial "fertilisers are necessary to ensure satisfactory growth in "replanted clearings.

"While good growth may result from the use of a single "fertilising ingredient, it should not be overlooked that the general "development and future yielding capacity of the trees may be "adversely affected if other ingredients are withheld in the early "years. It should be emphasized that the manuring programme "at present being recommended in Ceylon and Malaya are based "on very incomplete knowledge, and will doubtless need to be "modified in the light of the results of critical experiments.

"Most of the replanting seen in Java and Sumatra was on "fertile volcanic soils, and manuring appeared to be unnecessary "except in poor areas of limited extent.

General Impressions

"One of the earliest impressions that a visitor from Ceylon "receives on entering either Malaya or the Netherlands Indies is "the large scale of the individual planting organisations. Where "we deal in hundreds of acres they deal in thousands. The largest "companies form units which are almost self-contained, and have "their own scientific officers, engineers, workshops, etc. The two "most striking instances are the Anglo-Dutch Company in Java "and the H.A.P.M. in Sumatra, the Headquarters of both of which "constitute small townships of their own. Such centralisation is "of course, the outcome of a general process of rationalisation "and, except where carried too far, obviously leads to greater "efficiency and cheaper production. The small size of the average "Ceylon estate is an intrinsic handicap which will probably never "be completely surmounted, but at the same time I formed the "impression that centralisation of management can be, and in "some instances has been carried to excess. Where the Manager "of an estate of 10,000 acres is responsible not only for the large "amount of office work commensurate with so big a charge but "also for the field and factory operations, it must be extremely "difficult for him to exercise adequate supervision over all the "work for which he is responsible. On the H.A.P.M. group of "estates, some of which are considerably larger than 10,000 acres, "the problem is solved by having an entirely separate staff for "the central factory and a number of special Tapping Inspectors. "Some of the larger estates in Malaya, however, are not so well "organised, and I thought that the standard of work—particularly "tapping—was higher on the estate of 2,000 to 3,000 acres than "on the larger unit.

"In general, I found that the attitude towards Rubber "planting was rather more—for the lack of a better word—"com-"mercial" than in Ceylon, at any rate on the properties controlled "by British Companies. The comparison of Ceylon, as a small

" manufacturer of hand made goods, with Malaya and the Nether-
" lands Indies, as highly organised mass-production organisations,
" is not altogether inapt. In my opinion the Ceylon producer
" regards the Rubber tree too much in the light of a permanent
" article of household furniture, not realising that with the con-
" tinual improvement in planting material any tree, however
" excellent its condition, becomes obsolete within a period of, at
" most, 30 years. It is often stated that the bark constitutes the
" capital of a Rubber estate; it would I think, be more appropriate
" to ascribe this function to the top soil.

" The presence of Tea, as the major European industry in
" Ceylon, is a mixed blessing. It has provided the younger Rubber
" industry with an agricultural background, but has detracted from
" the specialisation on which efficiency must be based. So many
" Superintendents and visiting agents work, or have worked, on
" both crops that the remark " of course I am really a Tea man "
" is heard far too often from those in responsible positions in
" regard to Rubber. Most of the superintendents whom we met
" on the tour appeared to possess a more specialised knowledge
" of the crop than the average superintendent on the Ceylon
" Rubber estate. Add to this the keenness of the Dutch to explore
" new methods in the field and factory, and the fact that many
" of the managers' and assistants have received an agricultural
" training before coming to the East, and one of the reasons for
" the more advanced condition of the industry in the Netherlands
" Indies is revealed.

Research

" A study of the research organisations in the further East
" did not come within the scope of the tour, but a few general
" remarks may not be out of place.

" The necessity for agricultural research has long been
" appreciated in the Netherlands Indies, and it was therefore not
" surprising to find that the chief organisations in Java and
" Sumatra viz: the Proefstation West Java and the A.V.R.O.S.
" Proefstation, are extremely efficient institutions and that their
" services are highly valued by the planting community. The
" Rubber Research Institute of Malaya is of more recent origin,
" but after passing through many vicissitudes during the economic
" depression has emerged as the largest and most important
" centre for rubber research in the East. Here also, the advisory
" services of the scientific staff are greatly in demand, so much so,
" in fact, as to constitute an embarrassment to the conduct of
" research.

"All the institutions have been greatly handicapped by severe "reductions in funds in recent years, "production research" "having suffered in particular. At the present time large "quantities of material resulting from genetical work undertaken "before the staffs were reduced are reaching tappable age, and "new officers are being recruited to deal with the work. In- "creased expenditure can be more easily met in these countries "than in Ceylon owing to the greater elasticity of the methods "of financing the institutions, and fluctuations in personnel are "more easily dealt with from the point of view of housing owing "to their situation in or near large towns.

"It is pertinent to ask how Ceylon fits into the general "scheme of rubber research. A country with a relatively small "production must always be handicapped in the conduct of re- "search; unless producers are prepared to pay relatively more, "the funds available are commensurate with the production but "the number of problems to be dealt with is no smaller. (Here "it may be mentioned that the Rubber estate in Java contributes "approximately twice as much towards rubber research as the "estate in Ceylon.) The policy adopted by the Rubber Research "Scheme is to deal only with matters of special local importance "and to act, so to speak, as a clearing house for information on "more fundamental problems investigated elsewhere. It is "obvious, however, that the extent to which any country can rely "on the results of work carried out in another is limited, and the "particular lines on which research in Ceylon should be extended "are the improvement in planting material and investigations of "soil problems.

"Co-operation in research is always of value to the parti- "cipants, and it is the small country with limited facilities which "stands to gain most. During the course of my tour I found the "utmost desire for co-operation, and it is much to be hoped that "the friendly relations established with scientific officers in Malaya "and the Netherlands Indies will be cemented by regular inter- "change of visits. We can hardly hope to give visitors from these "countries as instructive a time as they can give us, but we can "at least assure them of a most cordial welcome.

15th January, 1937.

THE GIANT SNAIL *ACHATINA FULICA* (Fer)

Suggestions for Control

BY

F. Beeley

The recent discovery that a certain simple chemical substance when mixed with bran possesses properties both attractant and poisonous to snails has awakened considerable new interest in the subject of control of the local snail pest known as the Giant Snail, *Achatina fulica* Fer.

The Giant Snail, originally a native of Africa, entered Malaya *via* India, Ceylon and Burma about the year 1922. Commencing near the main ports it has spread practically throughout the Peninsula. It feeds gluttonously on many types of vegetable, herbaceous and shrub crops and plants, though fortunately grain crops are left unharmed by this animal. The introduction of natural forest growths in rubber estates has in some districts favoured the epidemic spread of the pest until it has assumed considerable economic importance. This and other snail and slug pests have frequently been known to cause considerable damage to young rubber and leguminous cover plants, while in mature rubber they have been found drinking the latex, and eating the sweet cambium layers of bark exposed by tapping, thus causing wounds. When it is realised that the snail population of a field of young rubber with a good ground-cover may be between 10,000 and 50,000 snails per acre, that the female snail lays upwards of 300 eggs per season and that these eggs may develop into full-sized adults 10 cm. long within a year, one can imagine the great potential danger which threatens local agriculture.

In the course of the past decade several excellent articles describing the giant snail pest have appeared in the local press and in Malayan and Netherlands East Indies scientific journals, the more important of which are listed at the end of the present paper (1, 2, 3 and 4) to enable the reader to investigate the matter more deeply if he so desires, as in this paper it is intended mainly to discuss possible methods of control of the pest in the light of the recent discovery.

The New "Meta" Bait

The exact origin of the discovery that 'Meta' is attractive and poisonous to slugs appears to be wrapt in mystery, but that it came

from South Africa seems certain, which affords some atonement for the fact that Africa seems to have supplied the eastern tropics with Giant Snails in the first place. However, in 1936, according to Gimingham and Newton (5), several letters appeared in British gardening periodicals stating that good results had been obtained by the use of 'Meta'-bran baits for destruction of slugs and snails. These workers therefore carried out experiments with the bait, using Paris Green and pure metaldehyde for comparison. They found that the best results were obtained by the use of the 'Meta'-bran baits. This has led to great interest being taken in Malaya regarding the economic possibility of using this chemical for the control of the Giant Snail and slug pests on rubber estates and in agriculture generally. 'Meta' dry fuel is usually sold in packets of 50 or 100 briquettes each about 2 ins. × $\frac{1}{2}$ in. × $\frac{1}{4}$ in., the packets weighing $7\frac{1}{2}$ and 15 oz. respectively. Chemically it consists of commercial metaldehyde which is a polymerised (solid) form of acetaldehyde. It is used essentially for heating small domestic appliances such as kettles, smoothing irons, percolators, curlers, small grills, etc. It is manufactured chiefly in Switzerland and its manufacture and use is covered by patent in U.S.A., Great Britain, Canada, India, Japan, China and Australia. It is marketed by local chemists and dispensaries, while the local importing agents are Messrs. Diethelm and Co., Singapore.

Commercial supplies have now run out; one firm even stated recently that their London buyers were unable to obtain supplies owing to the sudden great popularity the preparation had obtained for use in control of slugs and snails in gardens, lawns, playing fields and golf links in Europe.

There is little doubt that in the course of the next few months the manufacture of supplies will be increased sufficiently to meet the demand. Present prices range from $1.30 per packet of 15 oz. at the Federal Dispensary, Kuala Lumpur to $1.71 per lb. in 10 lb. lots from London including freight. It is not a virulent poison to man, beast or bird, but it should not be placed wantonly in the reach of children or young animals. Dogs, cats and poultry will approach the bait, taste it and then go away. It is unlikely that they would eat sufficient to cause internal poisoning. In comparison with the copper and arsenical baits it may be considered as relatively harmless to man, beast and bird; in fact it is our experience that only slugs and snails seem to be affected; only occasionally has the author found a millipede or a beetle among the catch, and it is suspected that being attracted by the smell of the bran they succumbed to the caustic effects of the heavy slimy exudate of the dying snails.

Preparation of the Meta-Bran Bait

The apparatus required is very simple and consists of a bucket or glazed earthen-ware container for mixing the materials, large wood or metal spoon for stirring the mix and a pestle and mortar for breaking down the Meta briquettes to powder form—pressing between folders of strong paper will often suffice.

Supplies of Meta and rice-bran having been obtained, the powdered Meta is first mixed with a proportionate amount of rice-bran and the mixture wetted with water to a consistency of a solid mash easily handled or moulded into balls.

Experiment has shown that useful concentrations of Meta are of the order of $\frac{1}{4}$ oz. or $\frac{1}{2}$ oz. of Meta per one pound of dry rice-bran. There seems little object in increasing the concentration of Meta, and in fact it may be better to put down twice the amount of low-concentration bait than to use the stronger bait containing 1 oz. Meta per lb. of bran.

The bait may be distributed broadcast or may be placed in small heaps of one dessert-spoonful at intervals of 10 yards throughout the infested area. The bait is easily washed away by rain and it is recommended that a bamboo shield be placed over the lumps of bait if applied during the wet seasons.

In very heavily infested areas, especially over low-lying or swampy land, bait should be placed at more frequent points, say at 5 yards and the dead snails collected and buried each morning, leaving the bait exposed for a further catch.

Costs of Meta Bait

1. Meta ... $1.30 per packet (15 oz.)
2. Rice-bran ... $0.02 per lb.

Using the concentration of $\frac{1}{2}$ oz. of Meta for 1 lb. of Bran, one packet of Meta requires 30 lb. of Bran.

Total cost of dry materials for 31 lb. of dry bait = 1.30 + 0.60 = $1.90

It is estimated that one labourer should be able to mix 12 lb. of bait and place it out at approximately 10-yd. points—or better in alternate intervals between trees in alternate rows. This 12-lb. bait should be sufficient for an area of about four acres. Labour costs therefore will amount to about 20 cents per acre. Total costs per acre will be as follows:—

3 lb. of mixed bait	...	...	19 cents
Labour	...	...	20 „
Total	...	...	39 cents

At 5-yd. points the cost will be:—

10 lb. mixed bait	...	=	63 cents
Labour	...	=	30 „
Total	...	=	93 cents

Calcium arsenate-Bran Bait

This bait is prepared in a similar way to the Meta-Bran bait except that calcium arsenate is substituted for the Meta powder. This bait is cheaper than Meta but is dangerous to handle in that it is poisonous to other animals; poultry, dogs, etc., which may be tempted to eat it. Though not nearly so spectacular in action as the Meta-bait it has been shown to give fair results and, being more permanent in action, may be relied upon to keep an area free of snails for a considerable period of time. It serves as a useful bait for comparison with the Meta-fuel-bait.

Costs of Calcium arsenate-Bran Bait

Calcium arsenate is $6.00 for 28 lb. (I.C.I.).
Using 1 oz. per 1 lb. of bran
2 lb. of Calcium arsenate require 32 lb. of bran
34 lb. of bait cost 43 + 64 cents = $1.07 for dry materials
At 10 yd. points total costs per acre will be:—

3 lb. of mixed bait	...	=	9 cents
Labour	...	=	20 „
Total	...	=	29 cents

At 5 yd. points the cost will be:—

10 lb. mixed bait	...	=	30 cents
Labour	...	=	30 „
Total	...	=	60 cents per acre.

Calcium arsenate-Lime-Cement bait

This, even more permanent bait depends for its action upon the fact that snails need an abundant supply of lime for the purpose of making the shell. Limewashed posts and walls, old mortar and similar lime-containing materials are sought after by the snails and may therefore be used as a trap.

Suitable poison-lime bricks are made by mixing 1 part calcium arsenate, 6 parts slaked lime and 2 parts cement, by volume (or 1:4:2 by weight) with sufficient water to form the consistency

of an ordinary concrete mix, then allowing to solidify in slab form on a piece of paper. In a few hours the slabs will be hard enough to handle and are ready to be taken out to the field. The poison bricks will remain effective over a period of many months or even two or three years if placed in a reasonably dry situation.

Cost of Calcium arsenate-Lime-Cement bricks

Prices—Local

Calcium arsenate	...	$6.00 per 28 lb.
Lime	...	$0.75 per 133 lb.
Cement (*e.g.* Foot Brand)	...	$1.30 per 94 lb. bag.

Suitable proportions to give a medium hard brick are:—

1 part calcium arsenate, 6 parts lime, 2 parts cement by volume.

or 1 lb. calcium arsenate, 4 lb. lime, 2 lb. cement.

A 7 or 8 oz. briquette is sufficient for one bait.

In bulk

28 lb calcium arsenate	...	...	$6.00
112 lb. lime (slaked)	...	...	.70
56 lb. cement ...	...	...	.85
196 lb. material	...	...	$7.55

This is sufficient for 400—450 briquettes or roughly 2 cents per briquette including labour.

Experimental

A preliminary rough test of the various concentrations of Meta in the bran-bait and with bait at various distances apart was carried out on the lawns bordering the long grass of the swamp behind the laboratories at the Institute. Concentrations used were of the order $\frac{1}{4}$, $\frac{1}{2}$ and 1 oz. of Meta per 1 lb. rice-bran. Bait was laid at distances up to 10 yards from the border of long grass and it was shown that they were attractive up to that distance but less so than at the 1, 3 and 5 yds. distances. The experiment was spoiled, but with a total catch of 176 giant snails and 49 small spiral snails with $1\frac{3}{4}$ oz. of Meta and 3 lb. of bran in two days, excluding the number of dead snails carried away by the garden coolies, a sufficient indication was given that five yards distance could safely be allowed between lumps of bait without the risk of snails passing unaffected between them. The bait containing $\frac{1}{4}$ oz. Meta per 1 lb. of bran seemed to be rather weak, as the few snails attracted were still living on the third day, after which other insects, ants particularly, were carrying the bait away.

Further experiments were then laid down at the Institute's Experiment Station, using various concentrations of Meta in bran and with a calcium arsenate-bran bait for comparison.

Concentrations of the order ½ oz. to 2 oz. of Meta per pound of bran were used, each batch of bait being placed in a row at intervals of five paces through the area of well-grown leguminous bush-covers in an old cover-crop nursery known to be heavily infested with snails and bordering on the manager's garden. A distance of over 30 yards between rows of different baits was allowed to avoid possible interference between baits of different strengths. A bait of 2 oz. calcium arsenate per pound of bran was laid down in the same area for comparison. The dead or dying snails were counted and collected each morning over a period of 12 days, after which the snails collected were so few as not to justify further record. After the lapse of just over 2 weeks, while the calcium arsenate baits were firm and in good condition the Meta baits were being disintegrated and carried off by other insects. The resulting catch is given in the table headed Experiment I.

EXPERIMENT I

Site: Cover-Crop Nursery and Garden

Date: 24.11.37. No. of Dead Snails collected.

Bait: 1 lb Bran	½ oz. Meta	1 oz. Meta	2 oz. Meta	2 oz. Calcium arsenate
No. of baits	21 (=1 lb. mixture)	19 (=1 lb. mixture)	56 (=3 lb. mixture)	18 (=1 lb. mixture)
25/11/37 ...	534	540	767	210
26/11/37 ...	280	366	420	56
27/11/37 ...	196	210	180	14
28/11/37 ...	144	115	110	8
29/11/37 ...	86	86	64	6
30/11/37 ...	31	71	41	0
1/12/37 ...	23	41	28	2
2/12/37 ...	19	22	16	0
3/12/37 ...	14	14	13	0
5/12/37 ...	12	16	12	0
7/12/37 ...	11	14	8	0
Total ...	1320	1495	1559	296
Catch/1 lb bait	1320	1495	520	296

This experiment demonstrated clearly that there was little if any advantage in increasing the concentration of Meta over the ½ oz. per pound rate. In the 2 oz. Meta column, although 56 baits were laid, the area covered would be little greater than that covered by the single row of baits in the other columns. Thus little advantage is obtained by increasing the strength or density of baits above the 15-ft. point limit except that the kill is greater in the first day or two.

The Meta-bait is easily the more efficacious when compared with calcium arsenate bait.

A similar experiment was laid down the same day with concentrations of ¼, ½, 1 oz. Meta for 1 lb. of bran in another part of the same field.

The daily catch is shown in the table headed Experiment II

EXPERIMENT II

Site : Cover-Crop Nursery

Date : 24.11.37. No. of Dead Snails collected.

Bait: 1 lb Bran	¼ oz. Meta	½ oz. Meta	1 oz. Meta
No. of Baits	21 (=1 lb. Mixture)	19 (=1 lb. Mixture)	18 (=1 lb. Mixture)
25/11/37 ...	212	187	261
26/11/37 ...	86	98	96
27/11/37 ...	26	31	39
28/11/37 ...	11	16	23
29/11/37 ...	12	11	14
30/11/37 ...	14	10	13
1/12/37 ...	7	11	10
2/12/37 ...	9	5	6
3/12/37 ...	4	6	3
4/12/37 ...	0	0	0
Total ...	381	375	465

This clearly indicates that little advantage was obtained by increasing the concentration above that of ¼ or ½ oz. Meta per lb. of bran.

A third experiment was carried out to test the effect of calcium arsenate-bran-bait against that of Meta-bran-bait. The first part of this experiment commenced on the 25th November, 1937 and consisted of a direct comparison of groups of 20 baits totalling about 17 oz. of the bran mixture, laid down in the clean-weeded paths along the lines of rubber trees in the swamp area of Block 17 at the Institute's Experiment Station. An unbaited row of trees separated the baited rows. A concentration of 1 oz. Meta to 1 lb. bran was compared with 1 oz. of calcium arsenate in 1 lb. bran. The second part of the experiment laid down in nearby rows of trees in the same area compared ½ oz. Meta per 1 lb. bran with 1 oz. of calcium arsenate per 1 lb. bran.

The results are tabulated below as Experiment III.

EXPERIMENT III

Site: Block 17. Swamp Area. 1 lb. of each Bait divided into 20 portions.

No. of Dead Snails collected

Date	25. 11. 37		13. 12. 37	
Bait	1 oz. Meta/1 lb. Bran	1 oz. Ca. arsenate/1 lb. Bran	1 oz. Ca. arse. per 1 lb. Bran	½ oz. Meta/1 lb. Bran
1	635	285	786	396
2	576	54	480	98
3	140	20	367	36
4	54	6	140	17
5	51	2	98	5
6	46	0	61	0
7	50	0	37	0
8	36	0		
9	11	0		
10	0	0		

This experiment demonstrates the very small difference in efficacy between the ½ oz. and the 1 oz. Meta concentrations and shows the apparent superiority of the Meta baits over the calcium arsenate baits. It was again noted that after a period of about 10 days the Meta-bran-baits were being disintegrated and removed

by insects while the calcium arsenate-baits were still intact. A search of the cover-plants between the rows of trees indicated that the calcium arsenate-bait had caused many more deaths than was indicated by the number collected in the actual vicinity of the bait.

The photograph shows a typical sample of the types of Molluscs recently caught by the Meta-baits. The four larger snails are of the species *Achatina fulica* (Fer), the others, rarer species, some of which may occasionally be found attacking rubber trees. (All $\frac{1}{2}$ × natural size.)

Some interesting minor experiments have also been carried out in an attempt to determine the cause of the tremendous attractive power of the Meta-bran bait.

Three blocks of Meta were wrapped separately in thin tissue paper and placed in a conspicuous position near a known infested grassy swamp. After three days not a single snail appeared to have been attracted by the Meta, though living snails were observed in the neighbouring grass. On the fourth day one piece of the Meta was taken up, powdered, and while some was made into a rough bran-bait a little of the powder was sprinkled on tissue papers about 6 inches square and placed powder upwards near the original position of the bait. The bran-bait was also placed some 10 yards away along the same grass swamp border. After three more days, whereas the bran-bait had caught many snails, the two original blocks in paper had still no catch and only one of the tissue squares had caught one snail, which had probably wandered blindly on to the paper rather than been attracted.

Bran-mash without the poison is in itself fairly attractive to snails, but apparently not nearly so strongly as the Meta-bran mixture, but the fact is difficult to prove, as snails may eat the unpoisoned bran and wander back to their usual day-time shelter, while in the case of the Meta-bran the snails appear to be rendered incapable of leaving the vicinity of the bait. Thus Meta in its pure state has no attractant power for snails, yet possesses the property of increasing the attractant power of moist bran, and also that of being a violent poison to members of the Mollusca family.

Another interesting observation which has a bearing on the suggestions for field control of this pest was recorded from the writer's garden. This garden had been protected from snails $2\frac{1}{2}$ years ago by placing calcium arsenate-lime-cement bricks at strategic points on the boundaries and at the bases of the larger shrubs within the compound. Though very few of these poison bricks are now recognisable they appear to have been effective, for when recently 2 lb. of Meta-bran-bait was laid down only the

bait on the boundaries near a rubber field and near the road drain succeeded in killing about 40 snails, while the bait on the other boundaries and within the garden failed to make a catch, yet 2½ years ago this garden was considered very heavily infested.

Thus, while the above experiments demonstrate the phenomenal success in the use of the Meta-bran-bait for snail control they show that it is somewhat fugitive in effect, and for perennial crops such as rubber one should not lose sight of the advantages of the more lasting baits which would be more likely to keep an area permanently free of snails.

Hence, in conclusion it is suggested that for general estate purposes an area should be cleared of snails by the use of the bait of ½ oz. Meta per pound of bran, placed at 15 feet points; then protect the area from further invasion by use of the more permanent and reasonably safe calcium arsenate-lime-cement bricks placed at 15 feet points on the boundaries only.

Summary

A description is given of various experiments with concentrations of ¼ oz. to 2 oz. of Meta-fuel in one pound of bran as bait for snail-control. It is shown that ½ oz. Meta per lb. is the most suitable concentration for normal field use. It is superior in effect to calcium arsenate-bran-bait and calcium arsenate-lime-cement bricks but not so permanent as the latter. It is suggested that a combination of the Meta-bait and poisoned bricks would constitute a satisfactory method of control of the snail pest on rubber estates.

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Kuala Lumpur
22nd December, 1937

OIDIUM HEVEAE

Report on the 1937 Outbreak of Hevea Leaf Mildew

by

F. Beeley

The general failure of the North-East Monsoon winds to bring rain during the late months of 1936, and the failure of the same monsoon to produce the strong, dry, east winds usually experienced during January-February and the first half of March in 1937, were the most noticeable features of the Malayan weather before and during the "wintering" season of 1937. Only a moderately dry spell was experienced during the wintering and refoliation period in 1937.

The season November 1936—March 1937, was therefore noteworthy in that it gave an idea, for the first time during ten years of the writer's observations of the Malayan climate, of the type of weather Malaya would experience in the event of a failure of the monsoons. Such failure in other parts of the world is often followed by extremely drastic results, such as complete failure of growth of the crop, failure to ripen and harvest the crop, or by destruction of the crop owing to phenomenally rapid spread of diseases or pests. In Malaya, however, failure of the monsoons does not have this effect: the weather in the period in question in 1936/7 was in fact continuously that of the Maritime Tropical Rain Belt, unpunctuated by monsoonal influences. The usual heavy rains of November and December failed to arrive and these months showed rainfalls similar to other months of the year. On the other hand failure of the monsoon winds resulted in the absence of the usual dry period of January and February, instead of which these months showed heavy rainfalls as compared with the same months of previous years. After a moderate rainfall in December, January also proved to be only moderately wet throughout the country, though certain small areas such as North Kedah, Kuala Kubu district and the Malacca-Muar coastal regions, proved exceptions and had a dry month, the rainfall being below 5 inches.

In February and March the absence of the dry North-East Monsoon winds caused local conditions to have a dominating influence on local precipitation, with the result that freak rainfalls were recorded in many parts of the country. Very high rainfall would be recorded at certain places while at other stations within a few miles very low rainfalls were recorded. Similarly freak maximum and minimum temperatures were recorded. Local

atmospheric, electrical disturbances typical of the maritime tropical rain belt appeared to be chiefly responsible for these freak records.

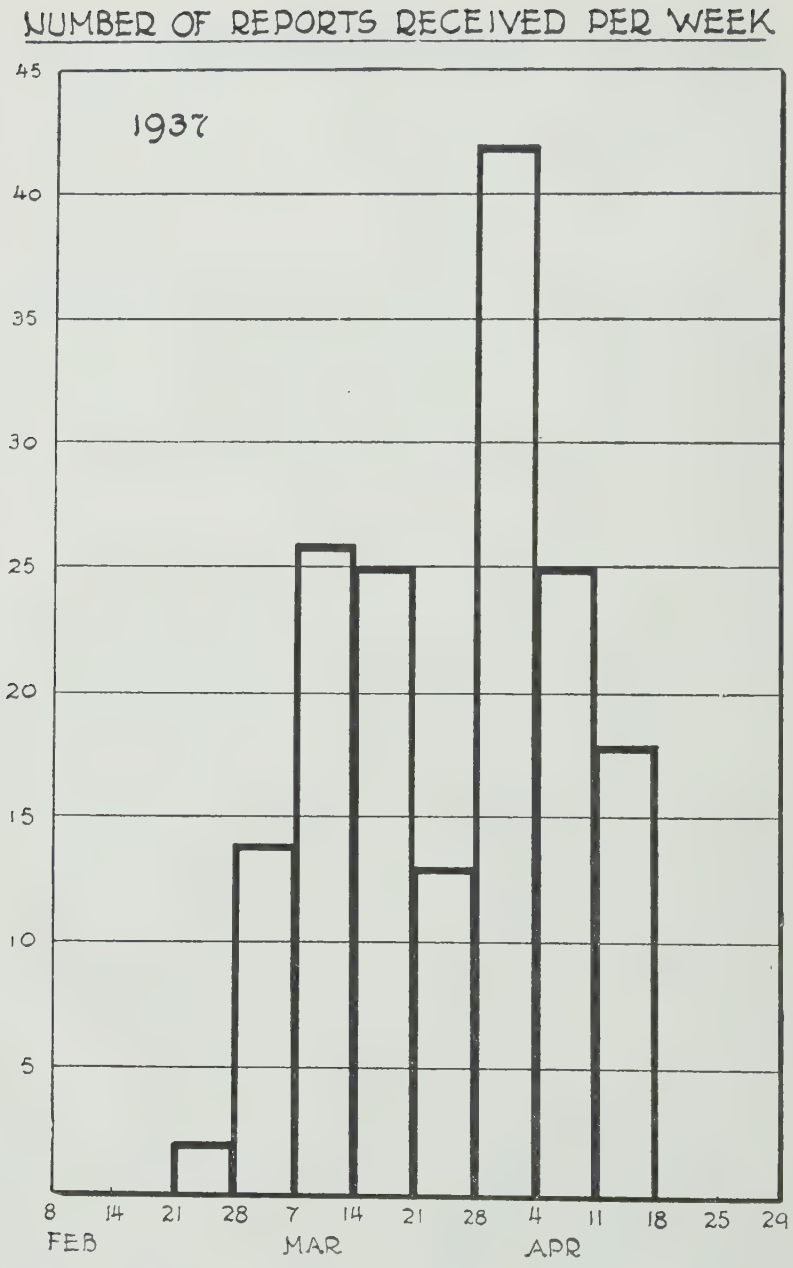
Realising the influence of rain on the wintering of rubber trees, it can readily be understood that considerable variation in severity of wintering at any one time was bound to occur, as was the case particularly in districts near the foot of the hills west of the main range.

The weather of the tropical rain belt,—bright sun with heavy thunderstorms later in the day—appears to favour rubber trees, with the fortunate result that in 1937, despite the absence of monsoon influences, the trees wintered and acquired a new foliage which was excellent in colour and size, having suffered from mildew only to a mild extent, and that only in certain late-wintering districts which are mentioned in the district reports below.

With the assistance of Mr. R. G. H. Wilshaw, Soils Chemist to the Department of Agriculture, S.S. & F.M.S., who also acted as pilot, an aerial survey of the rubber lands west of the main range was made early in March, with a view to determining the character and severity of the wintering in the various districts, and to ascertain the likelihood of a large area of rubber being in a state of refoliation such that, should weather conditions become suitable, it would be seriously attacked by Oidium Leaf Mildew.

This survey was interesting in that such variations in wintering and early refoliation as were observed could be attributed almost entirely to local conditions of weather, soils and topography, of which the soils or geological factors seemed to be of the greatest importance; the variations in wintering followed closely the general outlines of the geological map shown opposite p. 33 of this *Journal*, Vol. 7, 1936, with the added difference that areas in the latitude of 5° N. were some three to four weeks in advance of those in latitude 2° N. passing through southern, central Johore.

During the late-middle portion of March the weather in some districts between the coast and the foot-hills became rather dull, and there was a sudden influx of reports of occurrences of Oidium on the young leaves. The coast was apparently well protected by bright dry weather and districts further inland by bright weather with short intermittent local thunder-storms. The last week of March and the first two weeks of April were generally abnormally wet and dull in most districts between the coast and the main range, resulting in a rapid increase of leaf mildew, though not in very intensive form, being confined usually to the lower shaded branches. A fortunate return to brighter weather in the later half of the month completely stopped any further development of the disease.



East of the range the weather appears to have been rather dry on the whole, though later in the season a dull showery period gave rise to considerable fear that Oidium leaf mildew might assume serious proportions. However, such was not the case, as the usual sunny intervals proved sufficient to enable the new young leaf to mature rapidly and to throw off the disease.

The intermittent bright and dull periods proved favourable to the development of insect pests such as thrips, spiders, mites, caterpillars and leaf-eating pests generally, so that many specimens received for diagnosis were found to be damaged by these pests and associated leaf spot fungi and not by *Oidium Heveae*.

Reference to the table and graph shows the time of first-noticed mildew-attack in the various States. The number of reports received during the season, when compared with the previous year, shows that the outbreak occurred at approximately the same time in each year, and that the bright interlude in the second half of March corresponded with a reduction in the number of reports of disease.

On March 25th and 26th the writer made a tour by car to inspect the rubber districts north of Kuala Lumpur and in the following week a similar tour of the southern districts was made, in order to ascertain the extent and severity of the leaf disease and quality of the wintering and refoliation in the various districts. These observations, together with reports kindly sent in by estate managers, form the basis of the district reports given below.

TABLE I

OIDIUM HEVEAE 1937

REPORTS RECEIVED PER WEEK FROM EACH STATE OR SETTLEMENT

	February		March				April				
	15 — 21	22 — 28	1 — 7	8 — 14	15 — 21	22 — 28	29 — 5	6 — 12	13 — 19	20 — 26	Total
Johore ...			2	4		2	8	6	2		24
Malacca ...			2	3	7	4	5	1			22
N. Sembilan ...			7	15	13	4	6	1	2		48
Selangor ...			2	3	2	2	14	4	12		39
Perak ...		2			2		8	2	2		16
P. Wellesley ...					1	1		5			7
Kedah ...			1	1				1			3
Pahang ...							1	5			6
Total ...		2	14	26	25	13	42	25	18		165

JOHORE

The north-western coastal districts of Johore experienced a fairly early wintering as a result of a rather dry December and January. On March 5th, when examined by air, refoliation was well-advanced save in the valleys and peat flats where later wintering areas were observed. Similarly, central Johore, Kluang to Rengam, was only slightly later than the drier coastal districts. North Johore, though rather late, experienced an even and severe wintering of rubber trees. Younger areas were in most cases late and normally produced new leaf before the old had fallen.

Early in April some excellently refoliated areas free of disease were observed in the northern coastal districts around Tangkah, Muar, Batu Pahat and Ayer Itam, though occasional patches of late-wintering trees in low-lying land were observed to be infected by mildew and thrips in the lower branches. The rubber in central and southern Johore carried an excellent canopy of new foliage, only a few late-wintering trees in the older rubber being infected with the fungus. Thrips and mites were seen to be attacking some of the younger clearings. Variation in quality and size of leaf owing to varying fertility of soils, was usually found to be the cause of variation in foliage of different fields. In the northern districts, Labis to Gemas, the wintering was later and less severe, so that refoliation was late and of a very mixed character, some areas being bare of leaf, others in autumn tints and others bearing excellent new foliage. Trees in very young leaf were infected by Oidium only in lower branches.

MALACCA TERRITORY

Following a very dry wintering season in the north, the fall of old leaf had been early and complete, being followed by a rapid refoliation so that the new leaf-canopy was practically complete by the first week in April and few signs of leaf-mildew were observed, such being slight and present only in lower, shaded branches.

The Jasin district, however, was later and though much of the new foliage was very good some odd trees caught by the weather had been completely defoliated by Oidium in some cases and by thrips in others. A few trees still carried old brown leaf in April. Younger areas were in very good condition but both Oidium and thrips were observed to be present on the new foliage. This was also true of the southern parts of the Territory. Further inland, however, the new foliage was in excellent condition with little if any disease at the time of the writer's visit.

The improvement in foliage, so noticeable in 1936, appears to have been maintained during the 1937 season, though a slight increase in the number of reports of disease is recorded.

Negri Sembilan

Again wintering and refoliation followed a course similar to that of the past few years. Wintering was very severe over most parts while the inland districts at the time of the aërial survey showed a rather poor, pale yellow, new foliage developing in the areas of older rubber. At the time of the second visit this foliage had improved both in size and colour, suggesting that the earlier paleness of the foliage was caused by lack of water and mineral supplies to the tops of the tall, old trees.

Known manured areas were conspicuous by their later wintering, and in many cases they had new leaf developing before the old leaf had changed colour and fallen.

Trees on the peat and coastal clays were later and more desultory in wintering and refoliating, but the final result was very good, damage caused by Oidium, thrips, mites and spiders being restricted to the lower branches only, and only a few trees were observed completely robbed of their new leaf.

On the higher laterite soils north and south of Port Dickson the trees had wintered early and obtained most of their new leaf before the advent of the rather more showery weather late in March. The later-wintering trees had, however, been attacked by mildew, so that lower branches devoid of new leaf were frequently observed. Both Oidium and thrips were observed in active state in this district. In inland districts, Tampin to Bahau, wintering had been only moderately severe though early, so that some areas had obtained a healthy new foliage while others in valleys or at the foot of hills seemed to be still in a mixed stage having old and new leaf, brown foliage and bare trees all in the same area.

The monoclone blocks of rubber were interesting in illustrating the different inherent characters of the various clones in regard to wintering. The chess-board effect of a large area of monoclone planted rubber viewed from the air was very striking. One square would be completely bare with white soil showing dazzling though the empty branches, the next square a perfect even russet-brown owing to the old foliage, another a true coppery hue owing to the buds all bursting together and exposing the young copper-red leaf, and a nearby square all fresh, pale green, having wintered and refoliated early.

Little disease, however, seemed to be present except in lower branches of the latest refoliating trees, and by mid-April the foliage throughout this area was really good.

Selangor

During 1937 the central part of Selangor half-way between the foot of the hills,—Kuala Lumpur to Kuala Kubu,—and the coast,—Klang to Kuala Selangor,— was the most seriously affected district of all parts of Malaya visited by the writer. The coastal districts favoured by a long, bright, dry spell had wintered comparatively evenly and early, and the foothill regions though later had enjoyed sunny weather with afternoon thunderstorms also favourable to healthy development of foliage.

In the more central districts dull showery weather had delayed wintering and refoliation and at the same time favoured the spread and virulence of the mildew fungus. Thrips also appeared to be abundant upon the leaf throughout these areas.

More north around Kuala Kubu an abnormal dry spell in December and January had induced a very early wintering and early, healthy refoliation, so that by April the district stood out as being in advance of other districts within range of serial vision.

Generally the great increase in reports of leaf-fall from Selangor during 1937 may be said to be caused by the unfortunate climatic experiences of the districts lying between the coastal areas and the hills. Late April and May, being abnormally fine and dry, enabled these areas to make a quick and satisfactory recovery.

Perak

The districts between Tanjong Malim and Sungkai had experienced a later and more desultory wintering with corresponding slow refoliation. Trees late in refoliating were observed to be diseased in middle and lower branches. Other variations caused by soil and age were noted, some areas particularly around Slim had obtained an excellent canopy of new leaf and much less disease was present, though some areas of good new healthy foliage were seen also in the Tapah district. Further north in Kinta a greater variation in stages of wintering and refoliation was observed and is thought to have been caused by nutritional factors. Disease was present in all late-refoliating trees examined.

North of Ipoh was similarly very variable in condition. Around Sungei Siput, areas varied greatly with soil conditions; fertile land had early-refoliating trees putting out a second flush of new shoot and leaf by the first week in April, which in many cases was attacked by *Oidium Heveae*, but this was not regarded as of serious consequence as the canopy of healthy leaf already obtained was considered sufficient for the needs of the tree. The foliage of smallholding rubber trees near Kuala Kangsar was on the whole in good condition, with late trees carrying a mild attack. The district of

Gunong Semangol was generally poor in foliage owing to poor soil-conditions, late trees being badly attacked as a result of slow rate of development to maturity. The peat districts were well advanced and though a few trees near open clearings and root-disease-patches were diseased the areas generally had good healthy new foliage. Of the coastal districts Trong had, as in the previous year, a rather mixed wintering and refoliation with corresponding, sporadic, heavy attacks of mildew. Bruas showed considerable improvement and though late did not appear badly diseased.

Sitiawan and South Perak were also very late in wintering; though patches had refoliated successfully, the majority of old rubber areas were suffering from a mild attack of disease which was banished by the sunny weather of April and May.

Province Wellesley

Rubber trees on good soils in this district had completely refoliated by the end of March, acquiring a good, heavy, dark green foliage; occasional branches near clearings had suffered defoliation by either thrips or Oidium, or by both.

Some areas with poor foliage were observed to be late in refoliating and had suffered slight leaf-fall. The wintering generally in the north of Malaya had been less early than is usually the case, in comparison with the southern States.

Kedah

Though later in wintering than in 1936, the rubber trees of Kedah were in other respects in a similar condition to that reported for that year. The southern parts showed trees refoliating late in which spiders, mites and the Birds Eye Spot fungus *Helminthosporium Heveae* were active especially in younger areas.

In central Kedah the somewhat late-refoliating trees were attacked by both Oidium and thrips but not to any serious extent.

North of Sungei Patani the early foliage had completely escaped disease and as a rule the second flush of leaf-growth was attacked by leaf spot fungi and mites and spiders.

Pahang

From reports from estate managers in Pahang it would seem that the general improvement in foliage noted in the previous year had been maintained during 1937. A rather dry March favoured the earlier refoliation and it was not until the later showery weather arrived that reports of the presence of *Oidium Heveae* were received and it was stated that the lower branches of only the late-wintering trees were affected.

Summary

During the year 1937 the general improvement in foliage of rubber trees mentioned in last year's report has been maintained in most districts, the central parts of Selangor being the most notable exception.

The general failure of the North East Monsoon to bring its usual heavy rains at the end of 1936 and dry weather at the beginning of 1937 has given us a good idea as to the type of wintering and refoliation likely to occur under the normal climatic conditions of the Tropical Rain Forest Belt, the general indications being that such conditions are favourable to the development of the rubber tree foliage and unfavourable to an epidemic activity of the leaf-mildew fungus *Oidium Heveae*.

The number of reports (165) of the disease received from estates in 1937 is about the same as for the previous year (161). Similarly, owing to continual lack of virulence of the mildew-fungus under normal Malayan conditions, the sulphur-dusting programmes carried out in various parts of the country were severely curtailed to one or two rounds of dusting, or omitted altogether. The use of sulphur-dusting is finding great favour in the control of thrips, mites, spiders and leaf spot damage in young rubber in valuable rubber-seed-producing areas, and the time is coming when most estates will consider a motor or knapsack-duster as an essential part of estate equipment, which will give an added security against the possibility of heavy losses due to *Oidium Heveae* or other leaf parasites.

Thanks are due to the Adviser on Agriculture, Malay States, for placing Mr. Wilshaw's services at the disposal of the Institute in connection with the aerial survey.

Kuala Lumpur,
7th July 1937.

NODULE BACTERIA AND LEGUMINOUS COVER PLANTS*

BY

F. Beeley

It is a pleasant change from the usual lectures on harmful disease organisms to have to tell the story of the biology of the very interesting and agriculturally very important group of organisms known as the "Nodule organisms." These organisms were originally classified as variants of the species *Bacillus radicicola* but today the class is so great as to justify the generic term *Rhizobium* of which many species, specific to various plants, are recognised.

Ancient history yields ample evidence of the importance of nodule-bearing leguminous plants in mediaeval agriculture and earlier not only in Asia but also in the old Inca American world where both the food-value and the soil-fertilising value of these crops were early appreciated. Later in Egyptian and Roman times we find abundant evidence of the part played by Leguminous plants in agriculture and in religious and funeral rites.

In later European agriculture about the nineteenth century various workers demonstrated the fertilising value of cultivating a legume crop with cereals in order to obtain better yields of the latter. This was soon enlarged upon and the modern idea of rotation of crops became established. The problem as to how the legume crops increased the fertility of the soil exercised the minds of many scientists during the later half of the nineteenth century. Various theories were put forward but it was not until 1886 that Hellriegel announced his great discovery of the beneficial activity of micro-organisms in the nodules, in that these micro-organisms absorb and fix nitrogen from the air and make it available to the plant.

Tropical forest countries are particularly rich in nodule-bearing leguminous plants. In addition there are other genera of plants which bear similar nitrogen-fixing nodules *e.g. Cycadaceae Podocarpus* and *Casuarina* sp. distributed in many Tropic and Temperate climates.

The *Leguminosae*

The terms 'legumen' and 'leguminous' are derived from the Latin verb "legere" to gather, and are construed to mean plants

* Lecture given at the Annual Conference of the Incorporated Society of Planters at Kuala Lumpur, on 18th September, 1937.

gathered with the hands and not cut in harvesting. Botanists, however, now use the term "legume" in a more restricted sense as meaning the characteristic fruit or pod of the *Leguminosae*. Hence the present day terms "leguminous plants" or "leguminous crops" when speaking of the plants themselves.

This large family of plants is easily recognised by the butterfly-like flowers, in which the two lower petals are united to form a keel and so enclose the stamen and pistil. There is a single free pistil which develops into the pod or legume, which is dehiscent by one or two sutures into two valves.

Today the family *Leguminosae* is the second largest in the plant world and representatives are found in all climates and soils from the arctic to the hottest tropical regions. They play a great part in the building up and reclaiming of soils. Even on waste tin tailings leguminous plants are among the earliest to establish themselves.

Campbell 1927 studied the revegetation of gravel wastes and of worn-out and abandoned farm land. In the first period of return to nature the *Leguminosae* may constitute 75-100 per cent. of the plant population. But as such soils again increase in fertility in consequence of the growth of the *Leguminosae* themselves, the flora changes. The *Leguminosae* recede and other plants come in. He even went so far as to suggest that the relative abundance of *Leguminosae* in any wild association of plants constitutes an ecological index to the fertility of the soil.

It is difficult to estimate the amount of nitrogen which these plants assimilate and to estimate what chemical value they are to the soil, while of the cultivated leguminous crops one has to consider both the market value as well as their intrinsic value in the agricultural system. Certain of the *Leguminosae* yield valuable foods,woods, oils, dyes and medicinal or poisonous products. It is even claimed that anophelene mosquitoes feeding partly upon juices of toxic leguminous plants are unable to spread malaria though carrying the parasites.

Agriculturally the value of leguminous plants is threefold. (a) as a food or fodder crop, (b) as fertilisers of the soil and (c) as cover plants.

Investigating how the legumes improve soil fertility Hellriegel found that though legumes in themselves cannot assimilate nitrogen from the air, yet through the symbiotic life of the micro-organisms in the nodules attached to their roots they are able to do so, to the joint benefit of plant, organisms and soil.

It may now be asked what is meant by the term Symbiotic life *i.e.* Symbiosis?

Symbiosis

The term symbiosis is derived from the Greek, meaning "living together," though modern usage, in view of the existence of the commonly-used terms parasite, saprophyte, epiphyte, etc. attributes to the word the more limited meaning "the association of *mutually beneficial* organisms, of which the nodule organisms of the *Leguminosae* and the mycorrhiza of a number of other plant genera (*Ericaceae*, Conifers etc.) are classical examples.

Several species of tropical plants are known to possess colonies of nitrogen-fixing bacteria in their leaves which are visible as flat nodules on the leaf lamina or as special processes on the edges of the leaf. The leaf of the well-known Tulip Tree (*Spathodea* sp.) is very common in Malaya, growing vigorously in most garden soils and is found to bear nitrogen-fixing nodules in abundance on its leaves. Among other genera of plants which bear similar nodules on the leaf are *Pavetta, Psychotria, Ardisia* sp. etc. It would be interesting to know to what extent these species have played a part in, or been used specifically for, the improvement of soils during the past few years on rubber estates where natural covers have been established. Of the *Leguminosae* practically all species bear the nitrogen-fixing nodules on their root systems providing the correct symbiotic organism is present in the soil in which they are growing. There are however, a few exceptions. While the subfamilies *Papilionoideae* and *Mimosoideae* (except an Acacia sp.) generally bear nodules; the *Caesalpinioideae* show several exceptions which to date are *Cercis* sp. *Gymnocladus* sp. *Gleditsia* sp. and *Cassia* sp. Some authorities suggest that these may have other means of maintaining symbiosis with nitrogen-fixing bacteria.

It is important to remember that there are many different strains of nodule organisms, each specific to a certain species or group of plants, and of no use to other legumes. Unless the particular strain of nodule bacteria specific to a given legume is present, that legume is unable to form nodules and to assimilate atmospheric nitrogen, even though other strains of nodule bacteria specific to other plants are present.

Types of Nodules

Firstly note the difference between true symbiotic nodules and false nodules. There are two recognised types of false nodules produced, (a) by the nematode *Heterodera radicicola* a tiny eel-worm; and also (b) by the crown gall bacterium *Phytomonas tumefaciens*. Either of these false nodules may be found on leguminous plants bearing also true nodules.

The nematode nodule usually takes the form of swelling or enlargement of the root cylinder. The crown galls are usually found at the crown of the root and are of an irregular shape very different from the bright coloured, rounded, nitrogen nodule.

True Rhizobium nodules, when young, are usually of a smooth rounded, elongated or clubshaped form. As the first nodules grow in size other nodules may bud off from the larger ones thus forming a cluster or mass of nodules.

Generally speaking cultivated annual *Leguminosae* have large, spherical or irregular nodules. Perennial *Leguminosae* tend to develop smaller nodules in elongated clusters. Specimens of nodules of the more common legume cover plants and of eelworm nodules are shown. The number of nodules to be found on any single plant ranges from a few to several thousand widely distributed over the tap and lateral roots. The greater number of nodules does not necessarily mean greater benefit to the plant, in fact some authorities are of opinion that a few large nodules on the main roots and more on the base of the stem are more efficient from the point of view of nitrogen fixation and benefits to the plant.

Isolation of the Nodule Organisms in Pure Culture

If due care is taken and absolutely clean technique is used it is comparatively easy to obtain pure cultures on ordinary bacteriological media.

The procedure is as follows:—

1. Select nodules only from vigorous plants, and select true nodules of a plump, healthy rosy colour, avoid nematode nodules, root swellings and galls.

2. Wash the nodules free of earthy matter in a stream of water.

3. Clean and sterilise the external coat of the nodules by immersion for 2 to 3 minutes in a 0.2 per cent. solution of mercury perchloride in water acidified with a few drops of hydrochloric acid.

4. Wash in successive changes of sterile water for at least half an hour.

5. With sterile forceps place the nodules in a sterile glass petri dish, and then cut them up with a sterile scalpel and place the pieces into a tube of nutrient agar squashing them on the inside of the tube then smearing the nodules over the surface of the agar slope.

Growth on the agar slope is usually satisfactory after about 3 or 4 days incubation at room temperature.

Sometimes several different organisms may be obtained from the same nodule, in which case the various types must be inoculated into nitrogen-free liquid tube cultures containing a living plant of the same species as that from which the nodule was taken. The organism reproducing nodules in these plant cultures is the one required.

Several cultures from cover plants used in rubber agriculture are shown in the exhibits demonstrating the production of nodules on *Centrosema pubescens*.

Requirements of Rhizobia in Culture

It has been stated above that reasonably good cultures of these bacteria can be obtained on ordinary bacteriological culture media. The writer normally uses D.I.F.C.O. Dextrose agar or Potato Dextrose Agar. Agar media made from vegetable extracts have not given such good results as Dextrose Agar.

Some authorities, however, prefer to use special nutrient solutions and solid media containing no nitrogenous substances, in order to limit the specific growth to that of the atmospheric nitrogen-assimilating organisms. The use of such media for the purpose of isolating these bacteria may give very misleading results and often serves merely to hide lack of attention to correct manipulation and technique. The medium in general use to-day is one of these, namely, Mannitol-Phosphate agar, upon which some of the nodule bacteria can thrive but others scarcely grow at all. When a culture is received in this laboratory from other countries it is subcultured on to a number of media in order to find upon which medium it will grow best, and in this way cultures which appear to have made no growth on the medium upon which they have made their long journey and are at first labelled dead or suspiciously so, often prove to exhibit vigorous growth on the Dextrose Agar.

Laboratory culture has shown that these organisms require particularly calcium, potash and phosphates together with an abundance of fresh air. If tubes are sealed or tightly plugged with cork, growth is poor and death of the cultures soon takes place. Light plugging of tubes by cotton wool, or daily aeration of liquid cultures serves to ensure as long a life as possible for these cultures.

In the liquid tube cultures good growth of both plant and organism has been obtained by blowing air each day through the long piece of glass tubing which is inserted in each culture tube.

The liquid for the cultivation of both plants and Rhyzobia consists of the following:—

Potassium Chloride	1.00 gm.
Calcium Sulphate	0.25 gm.
Magnesium Sulphate	0.25 gm.
Calcium Phosphate	0.25 gm.
Ferrous Sulphate	0.25 gm.
Distilled Water	1,000 ccs.

The plants are usually obtained from washed sterilised seed germinated in sterile sand in covered dishes. When ready for transference at 7—14 days old, as much sand as possible is washed from the roots by sterile water and the seedling placed in the cotton wool plug of the tubes which have previously been sterilised in the autoclave. The tubes are then jacketed with black paper to keep off the light from the roots and inoculated with a sterile platinum loopful of the culture under test. The plants are then exposed to light for a few weeks taking care to aerate the tubes each day. In the case of *Centrosema*, nodules will appear within 3—6 weeks if the culture is of the right type.

Requirements of Nodule Bacteria

Some authorities say that temperature, sunlight and acidity have considerable effects on the growth and efficiency of the nitrogen-fixing nodule bacteria. It has now been shown fairly conclusively that these organisms can withstand temperatures of 0°C to 50°C (32 to 122°F) showing optimum activity and growth at 20 to 28°C (68—82°F). Hence their occurrence in both Arctic and Tropical countries. They are tolerant to moderate sunlight and even ultra-violet light if not exposed for too long, though they thrive better in comparative darkness. Although most of the known species flourish under neutral or only slightly acid conditions they are known to be tolerant to acid and alkaline soils in which they develop variant types adapted to the particular reaction of the soil in which they are growing. This formation of variant types under different soil conditions is of importance in Malaya, where one finds not only variation in texture and composition of soils but also in the degree of acidity of the soils, most of which are decidedly acid.

The wide range of tolerance of these organisms gives good cause to believe that leguminous cover plants can be grown successfully on most Malayan rubber lands.

Mechanism of Nitrogen Assimilation

Various theories have been put forward by biologists to explain how the atmospheric nitrogen is absorbed and combined with the elements in such a way as to provide nitrogenous compounds suitable for absorption into the plant or for excretion from the roots into the soil.

It is known that the ordinary rod-shaped Rhizobium undergoes various changes in its life cycle within the nodule. Some of these changes involve the formation of bacterioids which are protein bodies unrecognisable as bacteria. It is thought that these bacterioids are, by digestion, absorbed wholly or in part, by the plant, thus supplying protein required for the growth of the plant. That such transference does occur can easily be demonstrated in culture work and in the field.

Most of the Rhizobia, when in vigorous growth, form a mucilaginous matrix of carbohydrate nature, which some authorities assert is capable of absorbing nitrogen from the soil air and transferring it into protein compounds. Another explanation is that the bacteria themselves are capable of absorbing nitrogen, transferring it into protein compounds in their own bodies, which, after death, are digested by the plant-root juices into lower protein compounds and, as such, transported to other parts of the plant. The very high birth rate and death rate of these organisms must render available comparatively large quantities of nitrogenous material which is, surely, absorbed by the plant.

In the cultures exhibited there are abundant free Rhizobia in the liquid and it seems reasonable that these organisms derive carbohydrate food from the juices exuded by the roots, while in return these roots will receive the digested bodies of the dead bacteria to the ultimate benefit of the plant. In the cultures inoculated by organisms which have failed to utilise the root juices of the plant growing thereon, no such multiplication and death of these organisms can take place, and the plant receiving no nitrogenous food must succumb. Thus, in such critical cultures a truly beneficial relationship between plant and organisms must obtain to produce the required growth of both.

Laboratory Experiments with Nodule Bacteria

During the last few months eleven species or varieties of *Rhizobia* have been isolated from various cover plants normally used on rubber estates in Malaya, and in addition Mr. Hamilton of the Soils Division of the Rubber Research Institute has obtained from Rothamsted and from Wisconsin U.S.A., some sixteen pure cultures of Rhizobia isolated from the *Leguminosae* of subtropical and temperate climates, which are now being subcultured and

tested for their nodule-forming properties on local cover plants, *Centrosema, Desmodium, Vigna, Pueraria, Tephrosia, Crotalaria* sp. etc.

In the tube cultures exhibited, the Centrosema plants were inoculated when about ten days old by the application to the roots, under sterile conditions, of a small drop of a vigorous culture of the organisms on agar. Air was blown into the tubes daily and the water level maintained by the addition of more nitrogen-free mineral solution as required. There was no drainage or changing of the liquid in the tubes.

In the case of some of the species of Rhizobia, nodulation was visible within two to three weeks. Photographs were taken at intervals of four and eight weeks after inoculation.

The results, briefly, are as follows:—

(1) Nodulation beneficial to both plants and organisms can be obtained with cultures derived from field plants of the same species as the one inoculated. Of the three varieties of organisms obtained from *Centrosema* there are indications of a difference in vigour and nodulation properties of each.

(2) That vigour of growth and depth of green colour of the *Centrosema pubescens* varies directly with the size and degree of nodulation upon the roots. Under the conditions of these experiments support is given to the theory that the development of large nodules, few in number and concentrated high up on the tap root and main lateral roots, is the desirable type of nodulation and is indicative of true symbiosis and positive benefit to the plant.

(3) Other species of *Rhizobia* have no effect or produce non-beneficial nodulation, resulting in ultimate death of the Centrosema plants.

(4) One species of organism, while producing fair nodulation, has a detrimental effect upon growth of the *Centrosema*. In this case the organism is living entirely parasitically upon the cover plant.

It is noticeable that in the tubes containing plants free from nodules the aerial parts are starved in order to afford extra root development in an attempt to find a source of nitrogenous food.

(5) There is also some evidence of antagonism between organisms when a mixed culture is inoculated into the roots. If a nodule organism specific to the plant inoculated is used then successful nodulation may be expected, but if a second non-specific species is used the amount of nodulation may be reduced and the benefit to the plant correspondingly reduced.

(6) The *Rhizobia* isolated from *Pueraria, Mimosa*, Soya Bean produce no nodulation or other beneficial result when inoculated on to the roots of *Centrosema pubescens*.

There are, however, recognised groups of organisms of this type which will cross-inoculate into groups of plants other than that from which they were originally obtained. Experiments are now in progress to test the specific character of all the organisms now in culture and also to find which organism will cross-inoculate into other leguminous species with a view not only to finding the beneficial types, but also to finding the inhibitors and truly parasitic types of nodule organisms, species for species.

The importance of the latter is only just now being realised and several workers in this sphere of biology have discovered that the much dreaded phenomenon known as Clover Sickness, Soil Sickness, or Legume Sickness is very probably due to inhibiting factors such as the presence of pirate bacteria, truly parasitic or ineffective strains of nodule bacteria.

Field Inoculation of Leguminous Cover Plants

The above experiments have a very important bearing on the problem of inoculation of cover plants in the field. Dealing with *Centrosema pubescens,* it is found that several species of *Rhizobia* are capable of producing beneficial symbiosis. These several species have been isolated from Centrosema plants obtained from areas of different soil types and the probability is that these organisms are variants of the one species and have probably adapted themselves to their respective local environment. It will therefore be necessary to exercise considerable care in selecting the culture with which the new crop is to be inoculated. There will no doubt be a tendency to use mixed cultures of *Rhizobia,* in order to increase the chances of obtaining the correct one. This, however, is shown to be a risky procedure in view of the chance of inoculating into the soil organisms which, even if not true parasites, may inhibit the production of beneficial nodulation.

In other countries various proprietary preparations have been advertised and used for inoculation and improvement of leguminous crops with very mixed results. The tendency to-day is to disregard preparations containing mixed soil cultures of doubtful or even unknown specificity and to use only bacteriologically pure cultures of the organism specific to the particular crop it is desired to grow.

Laboratories have been set up by many Agricultural Colleges and Research Stations and by the leading seedsmen and plant breeders, in which cultures are obtained from leguminous plants and thoroughly tested to determine their specific nature. To-day, therefore, it is possible to obtain a pure agar culture of the particular strain of organism which has been found to give

maximum benefit to the crop for which it is required, a very different thing from the pot of soil, taken from an area where that crop used to grow well, one would have received some quarter of a century ago.

Several methods are in vogue for the inoculation of soil or seed with bacteria. The more useful are as follows:—

(1) By transferring one or two tons of soil per acre from an area in which the cover plant is found to grow and nodulate well. This method would be ruled out in this country on account of cost.

(2) By inoculating the wetted seed to be sown with fine soil obtained from the roots of well-grown cover plants.

(3) By inoculating dry seed with a mud or paste made by adding a little water to the fine soil shaken from the roots of well-grown cover plant of the species desired.

(4) By rendering the seeds sticky with sugar, glue or casein solution, then dusting them with fine soil from the roots of the well-grown cover plant.

(5) By the application to the seed of suspensions of proprietary cultures of 'nitrogen gathering' bacteria. There are no local preparations of this type, and if there were it is likely that they would fail as in other countries, owing to lack of knowledge as to their specific nature and uses.

(6) By the use of composite cultures consisting of several species of *Rhizobia* specific respectively to various legumes. These mixed cultures, as shown above, while possessing some advantages, certainly have some disadvantages and are not to be recommended.

(7) By crushed nodule cultures. Nodules from well-grown cover crops are collected and crushed in water to form a milky fluid which may then be applied to the seed. This method has already given good results and deserves consideration.

(8) By inoculation of seed or soil with a water or milk suspension of tested pure cultures on agar media obtained from desirable forms of nodules of cover plants of the same species as that of the seed to be sown.

Application of Laboratory Results to Field Conditions

As long ago as 1928 the writer obtained many cultures of nodule bacteria from the cover-plant experiments set up on the Sungei Buloh forest soil in the early years of the present R.R.I. Experiment Station.

The experience gained in these early days has proved of great help in quickly producing fresh isolations from various cover plants, all of which are now being tested by the writer, in the Pathological Division of the Rubber Research Institute, for their specific

properties and for their effect when cross-inoculated into other species of legumes.

The Soils Division of the Rubber Research Institute is laying down a number of field experiments on different soil types with a view to determining the value of inoculation in establishing and maintaining covers in rubber areas, thus carrying into the field the results obtained in the laboratory by the Pathological Division, close collaboration between the two Divisions being a feature of the whole scheme.

The following is a brief outline of these experiments, for which Mr. Hamilton of the Soils Division is responsible:—

(1) *Centrosema pubescens* will be used as the test plant in the first instance.

(2) Site of plots to be in replanted areas and in mature rubber areas, under normal shade.

(3) The plots will be manured and the soil lightly forked over to about 3 inches depth.

(4) Some soil from the areas will be taken to the laboratories for critical culture tests.

(5) Various manurial treatments will be combined with the inoculation treatments.

(6) Good seed of *Centrosema pubescens* will be obtained and sterilised the day before sowing by immersion in hot water at 60°C for 20 minutes.

(7) The seed will be inoculated by taking a water suspension of the growth of bacteria on a 6 or 7-day-old agar slope culture of the organism to be tested. This suspension will be poured over the seed and allowed to dry for a few hours.

(8) Uninoculated control plots will also be kept for comparison.

Later other methods of inoculation of soil or seed will be attempted.

It will be noted that the hot water method of sterilisation of the seed is to be adopted. This is because the use of chemical disinfectants may have an adverse or even fatal effect on the thin water culture of the organism which is subsequently to be applied, if all the disinfectant is not first removed with sterile water. Also the hot water method can easily be applied with safety on the average rubber estate in Malaya, and in addition this method will improve germination.

Possible Reasons for Failure of Leguminous Cover-plants in Malaya

1. The species of leguminous plant may not be indigenous and may fail from inherent factors to adapt themselves to Malayan

climate and soils conditions. Many of the known, good leguminous, forage crops prefer or require a long season's growth culminating in flowering and seeding followed by withering of tops and a definite rest from growth, in cold or dry season.

In Malaya, growth with flowering and seeding is almost continuous throughout the year, affording little opportunity for a seasonal rest. However, most of the legumes now normally used as covers in rubber areas are able to do fairly well under Malayan climatic conditions if other conditions are favourable.

2. With the exception of coastal clay soils, most Malayan soils are inadequately supplied with phosphate for the satisfactory growth of legumes. Although Malayan soils are in general well supplied with potash, this also becomes a limiting factor in sandy areas and in old areas which have been badly eroded. It is possible also that calcium and magnesium may be inadequate for maximum growth, but this requires further investigation.

Aeration is another soil factor which may seriously interfere with the growth of legumes. Adequate soil aeration is necessary in order that the organisms can obtain the necessary nitrogen for assimilation. Aeration is only likely to become a limiting factor in clay soils, particularly badly-drained coastal clays. In this case drainage is the best remedy, although a certain amount of cultivation will also do good. The importance of aeration is proved in the laboratory by the fact that it is essential to blow in fresh air to the culture tubes either sand or N.free nutrient liquid, each day in order to obtain the formation of nodules and proper symbiotic activity.

3. *Shade.* Failure of leguminous covers usually occurs about the third or fourth year of growth, culminating in their complete disappearance from the area at about the sixth or seventh year, except in a very few isolated places where such species as *Vigna* or *Centrosema* or *Pueraria* have lasted surprisingly well.

The failure may be due to the effect on the foliage of lines of rubber trees gradually closing in and blocking out the effective necessary light rays. If this is so there seems little hope of establishing leguminous covers in mature rubber areas, unless a species or variety of the legume can be produced which is tolerant to shade.

On the other hand, leguminous covers are known to fail after a few years in cover crop nurseries where no shade is to be found. It would seem therefore that the shade question is not of major importance. Failure of legumes under shade is usually coupled with unsuitable soil conditions. If these are made suitable, it is possible that covers will persist under dense shade, as indeed

they do on many estates in Java and Sumatra and on some in Malaya.

4. *Seed.* The failure of legumes may be due to degeneration of the self-sown seed, assuming the parent not to be a true perennial, to which the answer is; "Supply new imported", or it may be due to a disease of the type known in temperate climates as "Clover Sickness" or Legume sickness mentioned above.

5. *Diseases and Pests.* Failure may be due to diseases of the legumes which have not yet received due attention. The extent and gravity of the NEMATODE (eelworm) pest of roots of legume cover plants is not generally appreciated. Yet an examination of the roots of failing leguminous cover plants almost invariably reveals the amazing ravages of this little-known microscopic pest, which is prevalent not only in Malaya but in other countries and is the subject of very strict official regulations regarding planting of legumes in most countries in temperate climates and many sub-tropical climates.

In the case of some of the more important forage legumes, agriculturists have produced species immune to nematode attack. This problem should receive special attention in Malaya if it is desired to established low-growing or bush leguminous covers on the more friable soils commonly found in river flats and other inland districts of Malaya.

The chemical control of nematodes in soil is one of the great stumbling blocks in modern agriculture and the pests can at present be kept in check by two possible methods, *viz.*

(1) By growing only immune varieties of legumes.

(2) By alternation of legumes with other, non-susceptible crops. This means that as soon as the legume crop begins to fail owing to nematode attack of the roots, then that crop must be removed or destroyed and other crops substituted over a period of several years.

6. *Lack of Bacteria.* It is possible that, as in some temperate countries, imported leguminous plants are unable to survive owing to lack of the requisite organisms in the soil for nodule production. As has already been explained, these nodule organisms work in symbiosis with the plant, deriving their organic food from the plant and in return supplying to the plant nitrogenous compounds which they have obtained by assimilation of nitrogen from the atmosphere of the soil. This can be remedied by inoculating the seed or soil as described above.

7. *Legume Sickness.* It has been found that in Malaya, as in other countries, several varieties or even species of the nodule organisms of the family Rhizobium may exist and that one variety may be found in or be suitable to some districts or soil

types and not to others. Similarly the organism commonly found in the nodules of one species of legume may be quite unsuitable for inoculation of other species, *e.g.* the organisms from nodules of *Pueraria* will not form nodules or support symbiotically the growth of *Centrosema* and vice versa. Some species may produce parasitic nodulation or may inhibit nodulation altogether.

Conclusions

During the past year or so there appears to have arisen a feeling in the planting world that natural covers were not going far enough in the scheme of regeneration of soil on rubber estates, and attention has again been turned to the possibility of establishing leguminous covers in old rubber areas. In this lecture I have tried to convey some idea of the biology of the legume plants and to indicate how this mutual beneficial growth can be used for the ultimate benefit of both crop and soil.

The specific character of the organism associated with the various species of leguminous plants in Malaya is stressed, and managers contemplating field or seed inoculation are advised to take great care to see that they are using the correct culture for the purpose in view and that the cleanest possible technique is used when handling such cultures.

Kuala Lumpur

17th September, 1937

Nodule Bacteria of Leguminous Cover Plants

PLATE I

Legume. *Centrosema pubescens*—Inoculated on 7.7.37. Photographed 5.8.37. *Left to Right.*

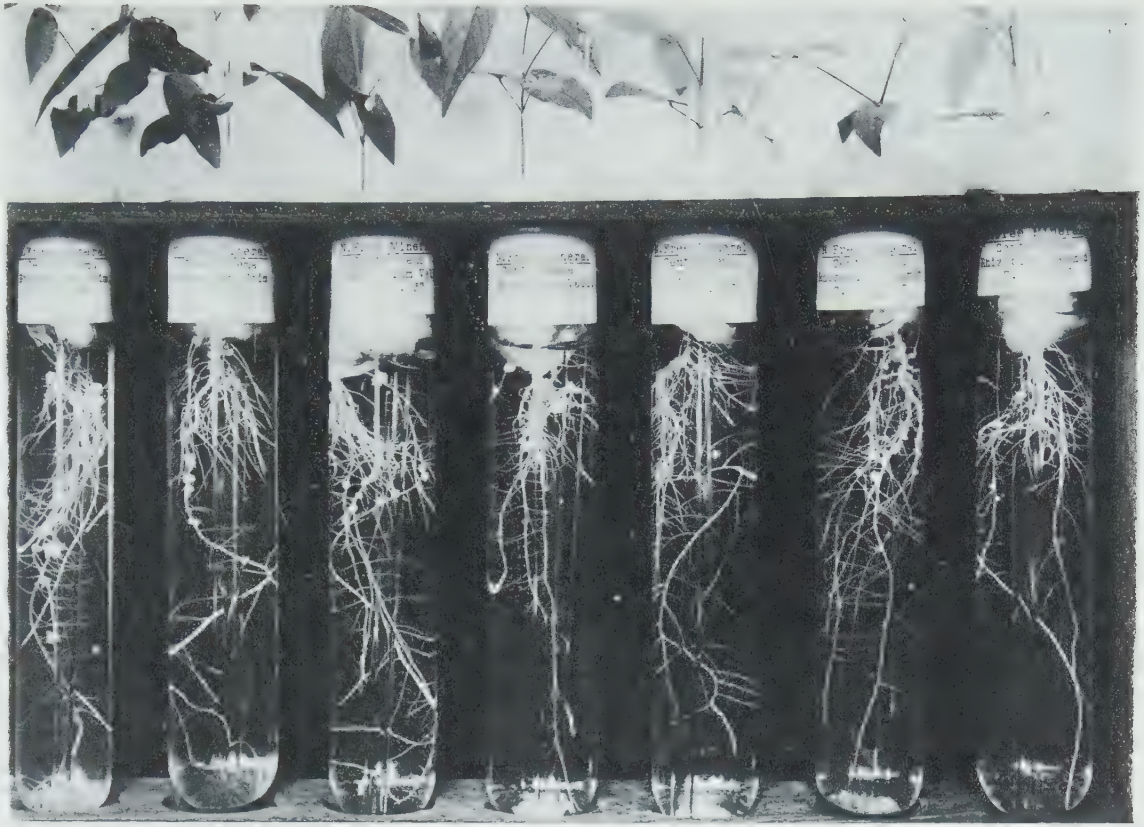
Tubes 1 & 2 inoculated with "Chim" organisms derived from *Centrosema* show excellent nodulation and excellent growth of legume plant.

Tubes 3 & 4 inoculated with "Vall" organisms derived from *Centrosema* from a different district show excellent nodulation and excellent growth of legume plant.

Tube 5 Control uninoculated shows no nodulation and poor growth of legume plant.

Tubes 6 & 7 inoculated with, Rhizobium derived from *Desmodium triflorum* show fair amount of nodulation of the truly parasitic type with the resultant poor growth of the legume plants.

PLATE I



Nodule Bacteria of Leguminous Cover Plants

PLATE II

Legume. *Centrosema pubescens*—Inoculated on 7.7.37. Photographed 5.8.37. *Left to Right.*

Tube (1) inoculated with the "Chim" organism as in plate I showing beneficial nodulation.

Tube (2) inoculated with a Rhizobium derived from *Mimosa* sp. No nodulation has taken place and the legume plant is poorly grown.

Tube (3) inoculated with the "Vall" organisms as in plate I showing beneficial nodulation.

Tube (4) inoculated with a Rhizobium derived from *Pueraria* sp. No nodulation has taken place and the legume plant is poorly grown.

Tube (5) uninoculated control plants also poorly grown.

Tubes 6 & 7 inoculated with Soya Bean organisms varieties (a) and (b). No nodulation and poor development of the plant has occurred.

PLATE III

PLATE IV

Nodule Bacteria of Leguminous Cover Plants

PLATE III

Legume. *Centrosema pubescens*—Inoculated on 7.7.37. Photographed 28.8.37. *Left to Right.*

Tubes (1) & (2) inoculated with "Chim" organism derived from *Centrosema* show excellent nodulation and excellent growth of the legume plant.

Tubes (3) & (4) inoculated with "Vall" organisms derived from *Centrosema* from a different district show excellent nodulation and excellent growth of legume plant.

Tube (5) Control uninoculated shows no nodulation and poor growth of legume plant.

Tubes (6) & (7) inoculated with Rhizobium derived from *Desmodium triflorum* show fair amount of nodulation of the truly parasitic type with the resultant poor growth of the legume plants.

This photo is similar to Plate 1 but taken 23 days later.

Nodule Bacteria of Leguminous Cover Plants

PLATE IV

Legume. *Centrosema pubescens*—Inoculated on 7.7.37. Photographed 28.8.37. *Left to Right.*

Tube (1) inoculated with the "Chim" organism shows beneficial nodulation.

A space has been left in order the better to demonstrate the excellent growth and deep green colour of the *Centrosema.*

Tube (2) inoculated with a Rhizobium derived from *Mimosa* sp. shows no nodulation and poor growth of the legume plant.

Tube (3) inoculated with a Rhizobium derived from *Pueraria* sp. shows no nodulation and poor growth of the legume plant.

Tube (4) Control uninoculated—poor growth.

Tubes (6) & (7) inoculated with Soya Bean (a) & (b) varieties show no nodulation and poor growth.

NOTES

ON THE

SELECTION OF RUBBER FACTORY EQUIPMENT

AND THE

MANUFACTURE OF SMOKED SHEET*

BY

J. H. Piddlesden

Introduction

Extensive improvements have taken place in the last few years in equipment for the manufacture of smoked sheet rubber on estates. The slump conditions of 1932 caused close attention to be directed to the reduction of sheeting and curing costs, and while much was done at that time to effect economies, other ideas emerged which were recognised as good, but which involved a capital outlay difficult to justify at that time. The improved conditions under Restriction have persuaded most Companies that such capital outlay could be justified, so that most factories now have up-to-date equipment consisting of aluminium-lined coagulating tanks, and power-driven, line-ahead sheeting batteries, and are so arranged that handling of the coagulum has been reduced to a minimum. The result is that estate factory work has been much improved, and that a cleaner, more uniform sheet is being produced at a lower cost. One result of the emphasis placed on the value of new machinery and equipment has been to induce a feeling that further improvements in sheet manufacture must, of necessity, wait on further improvements in tanks and rolling machinery.

Although work is being carried out continuously to this end, and it is dangerous to prophesy what future developments may be, it seems unlikely that there will be any far-reaching changes in the next few years. Manufacturing costs are now so low that a saving of 10 per cent. on the coagulation and machining costs would have an almost negligible effect on the f.o.b. costs of the estate. Thus, even if new designs are produced shewing savings of this order, those estates which have recently purchased

* Based on a Lecture delivered at I.S.P. Meetings in Kluang and Johore Bahru

new machinery will not find it economic to scrap the existing equipment and replace it with the new type, until the present machinery gets badly worn, or has been written off by depreciation. It is therefore apparent that attention to factory organisation, and the methods of operating existing types of machinery, present the most promising methods of attaining further economies. Any small reduction of cost obtained, for example, by reorganising the factory labour is a direct saving, since it does not have to be set off against the cost of new equipment.

Another consideration which has prompted the writing of this paper is that our recent experience of advisory work indicates that drying remains the most troublesome part of smoked sheet manufacture. Defects due to dirt, fermentation etc., have been largely overcome with present equipment, and the smoke-house remains to be blamed for most of the defects that now arise in smoked sheet. While it is true that the curing process is the most difficult one to control, and the one most likely to give trouble, the fact remains that by strict attention to details of procedure in the factory much can be done to facilitate the drying and smoking.

Ideal Conditions for Drying

The manifest advantages of rapid drying have been, if anything, over-emphasised during the last few years. Rapid drying has obvious advantages, in that a much smaller smoke-house is required to deal with a given daily crop, and space and capital outlay are thereby saved. A large saving in fuel is also frequently claimed for this method. The disadvantages of very rapid curing are less obvious but are none the less serious.

The two major ways in which drying can be accelerated are by the production of thinner sheet, and by the use of higher temperatures. Very thin sheet is not easy to produce, since close control over the coagulation is required, and the machines must be in good condition. Any wear in the bearings will cause the rolls to spring open as the rubber enters. Very thin sheet may prove difficult to handle as the lower ends tend to stick together when it is hung over *beroties*, and the massing together when the sheet is piled is more pronounced. The production of thin sheet reduces the output of the machines, thereby increasing the running costs. In some cases it would be necessary to reduce the dry-rubber-content at which the rubber is coagulated, in order to get thinner sheet, and this would involve more machining as well as increased expenditure on tanks. Finally, the thinner sheet occupies a greater space per lb. in the smoke-house.

The use of higher temperatures is also likely to give rise to difficulties, since this method involves the operation of the smoke-house at temperatures much nearer the danger limit at which blisters are formed on the sheet. To maintain an operating temperature near this danger limit, without damaging a proportion of the sheet, necessitates a close temperature control. This can be obtained automatically if heating is carried out by steam, oil, or electricity, but is almost impossible to secure with a direct wood fire. Another objection to the use of higher temperatures is that the heat loss from the smoke-house to the surrounding air is thereby increased. This heat loss is quite a large factor in the efficiency of the smoke-house. The heat lost by convection and radiation per unit area is given by a formula of the type

$$q = \alpha \left\{ \left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right\} + b \ (T_1 - T_2)^n$$

where α is a constant depending on the emissivity of the surface.

T_1 and T_2 are the absolute temperatures of the surface and the surrounding air, respectively.

b is an empirical constant approximately = 2.9.

n is an empirical coefficient approximately = 1.2.

A rough numerical example will best indicate the magnitude of the loss.

Assume α = 3.6 (which is the Peclet figure for brick or wood).

Let the wall temperature be 35° C = 308° Abs.

Let the air temperatures be 27° C = 300° Abs.

$$\text{Thus } q = 3.6 \left((3.08)^4 - (3.0)^4 \right) + 2.9 \ (8)^{1.23}$$

$$= 66.3$$

i.e. Heat loss = K × 66.3.

Now let wall temperature be increased by 3° C.

$$q = 3.6 \left\{ (3.11)^4 - (3.0)^4 \right\} + 2.9 \ (11)^{1.23}$$

$$= 84.1$$

i.e. Heat loss = K × 84.1.

Thus a 3° C rise in wall temperature gives an increase of 26.9 per cent. in the heat loss.

This disadvantage of increased heat loss may be overcome by paying careful attention to the thermal insulation of the building. No matter what working temperatures are used the effective insulation of the smoke-house is important, but as operating temperatures increase this problem becomes increasingly serious and expensive.

Finally, the curing process involves smoking in addition to drying. Thin sheet dried rapidly is frequently very pale in colour.

Such sheet is not only less resistant to mould attack, but there is also some prejudice among manufacturers against the use of this pale-coloured rubber. A corresponding preference for reasonably dark sheet has grown among buyers.

The arguments against the production of very thin sheet and rapid drying have been emphasised to shew that there is a limit to the progress which can be made in this direction, and it appears that this limit is being approached with the factory equipment and smoke-houses now available. It is possible to dry rubber in from two to three days, but for the reasons given it is still recommended that provision should be made for four days. A number of types of smoke-house in which sheet not excessively thin can be dried in four days are now available. Thus, with the smoke-house, as with the factory machinery, the immediate problem is to make the best use of the present types, rather than to evolve new types, since although there is undoubtedly scope for improvements in smoke-house design, changes are likely to be confined to those affecting ease of handling, and reductions in initial cost, rather than radical alterations in ventilation, drying time etc.

It thus becomes apparent that the immediate ideal for curing rubber is a smoke-house of a type which is already available, but which is economical and as nearly automatic as is possible. The process must be so arranged that once the degree of ventilation is set, and the labourer has been trained to keep a reasonably level fire, the rubber can be dried consistently to good quality sheet, with a minimum of supervision. This cannot be achieved unless the wet sheet which reaches the smoke-house is uniform. It is now proposed to discuss the factory equipment and processes, paying particular attention to those factors which can assist in the preparation of uniform sheet.

Factory Lay-out

All modern factories are arranged on one of two standardized systems. The earlier system employs two lines of stationary coagulating tanks butting on to a central chute which conveys the coagulum to the machine, as shewn in Fig. 1. This arrangement is improved by the use of the flooding system with which the coagulum may be floated over the end of the tank into the chute. In the more recent system the coagulating tanks are mounted in pairs on trolleys which run on a track at right angles to the centre line of the battery, and so arranged that each tank in turn may be pushed along until its end is opposite and close to

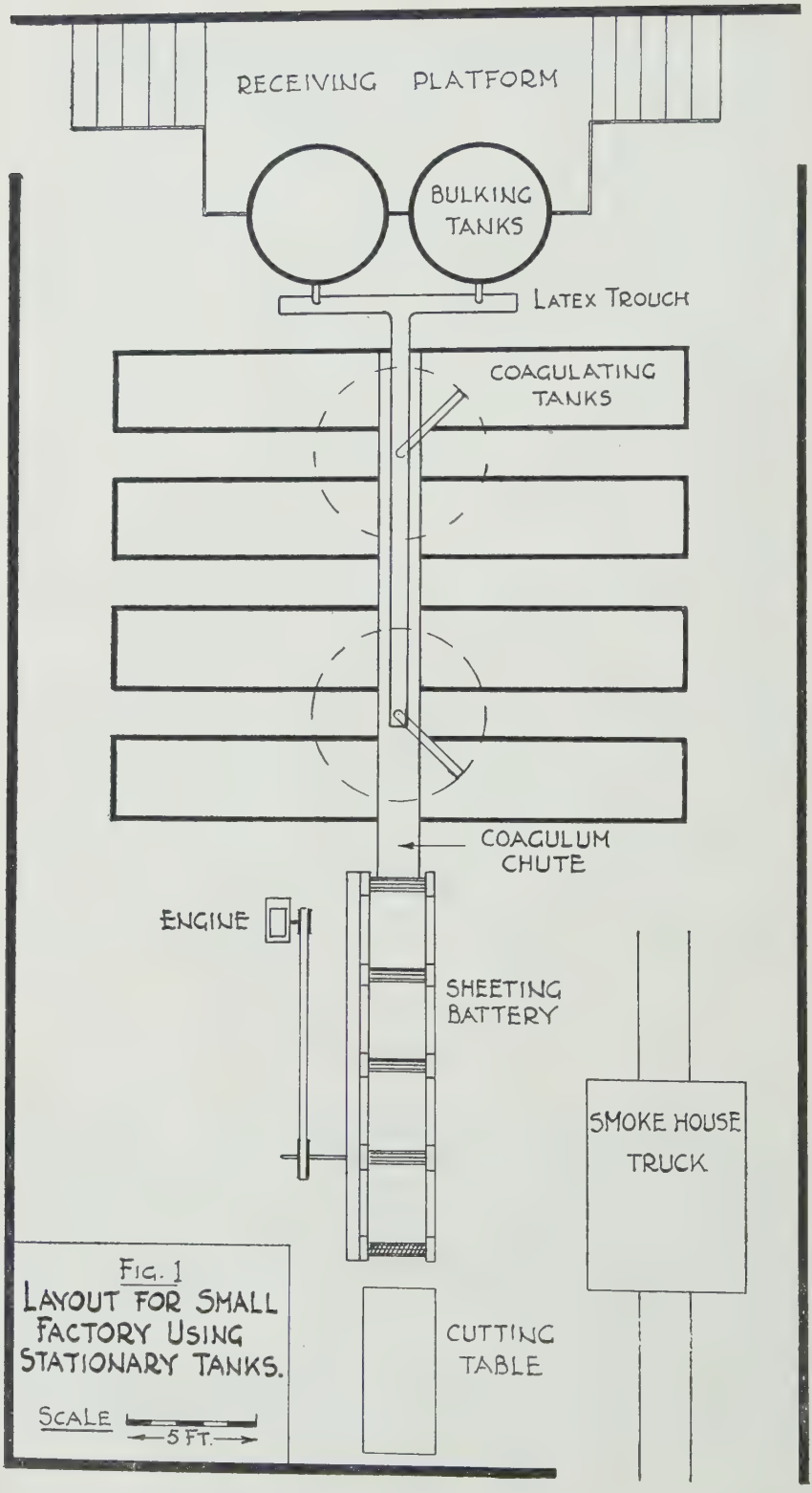


FIG. 1
LAYOUT FOR SMALL FACTORY USING STATIONARY TANKS.

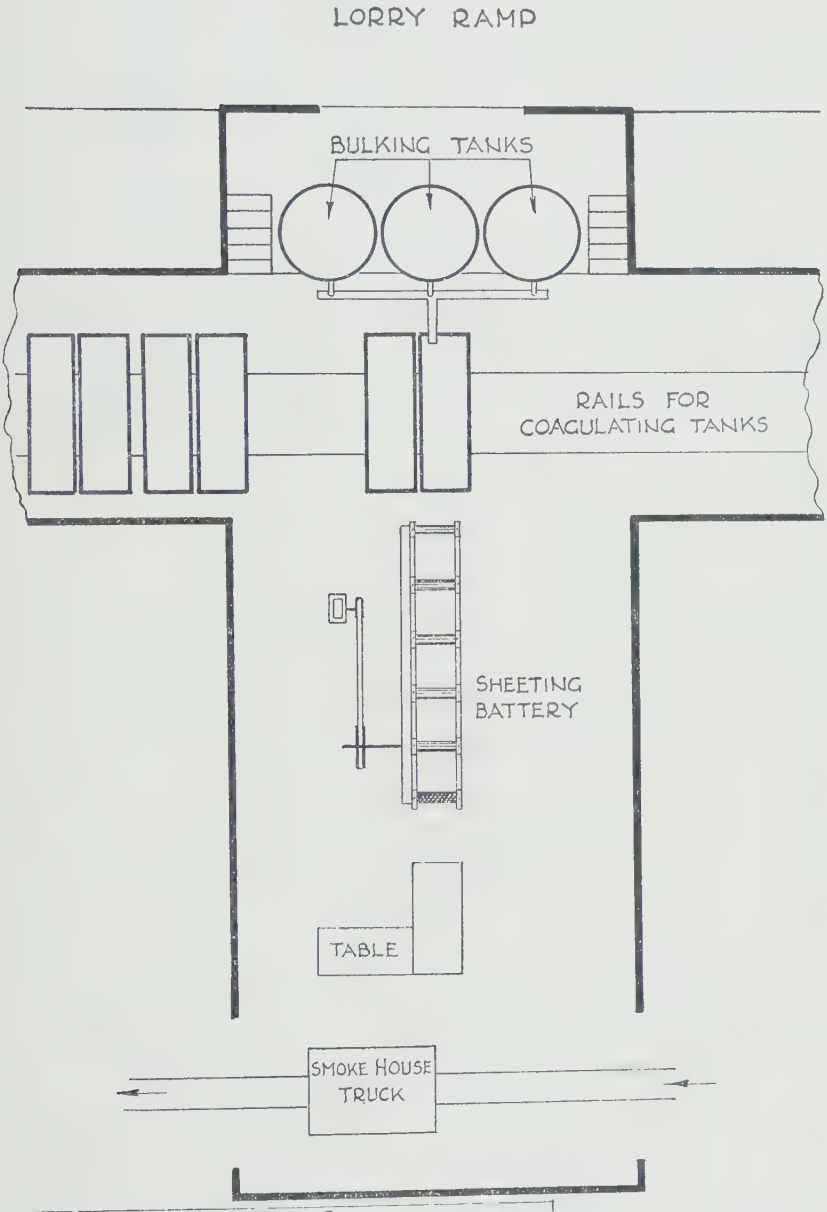


FIG. 2

LAYOUT FOR MEDIUM SIZE FACTORY USING TANKS ON TROLLEYS.

SCALE 8 FT.

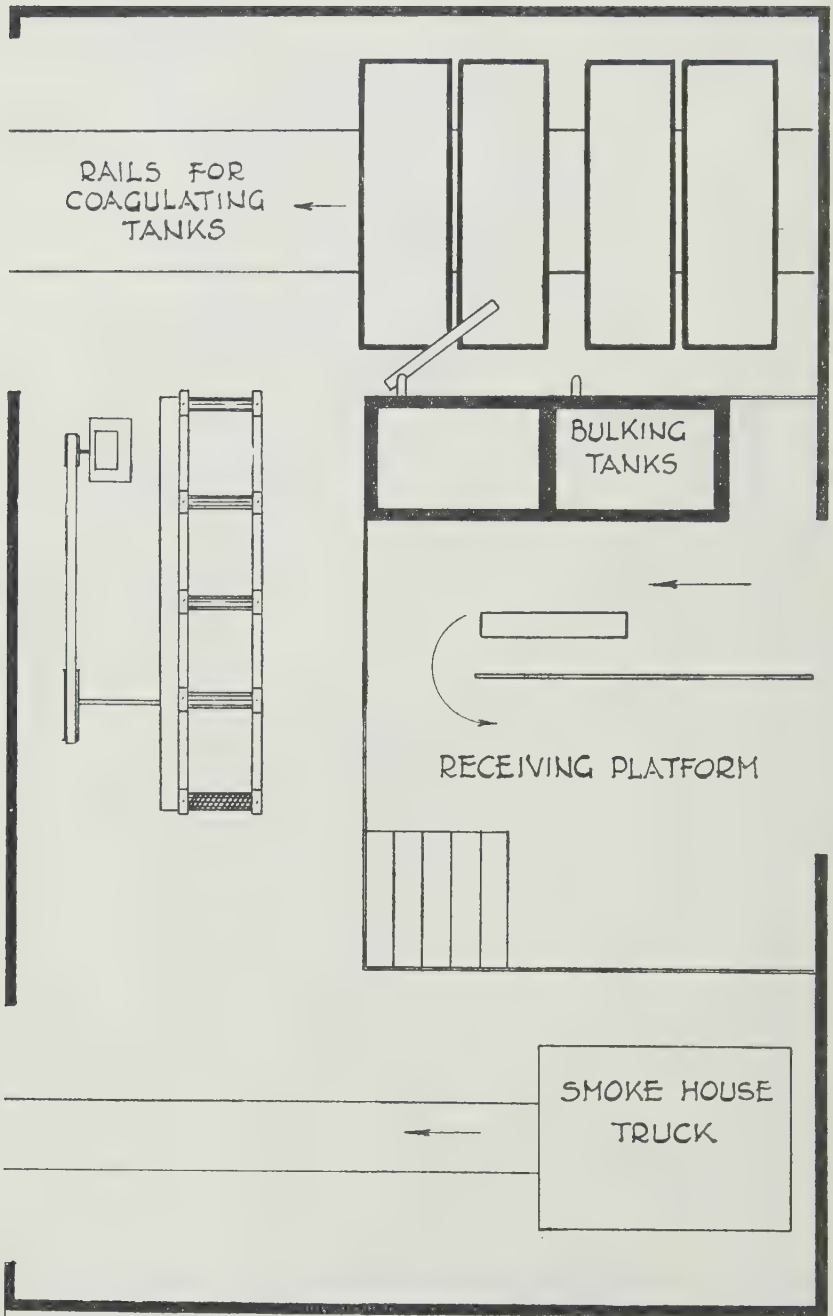


FIG. 3
LAYOUT FOR SMALL FACTORY
USING TANKS ON TROLLEYS.

SCALE ← 5 FT. →

the first pair of rolls, as shewn in Fig. 2. An interesting modification of the arrangement has been developed by Mr. D. J. Gibson of Beradin Estate and is depicted in Fig. 3.

For small estates, having not more than eight coagulating tanks, the central chute system either with or without flooding attachments is very satisfactory, and is cheaper in initial cost than the rail system. The arrangement shewn in Fig. 3 also gives a very compact factory and has the advantage of requiring less water. It also makes it possible to dispense with one labourer when high machine outputs are not required. With the fixed tanks it is necessary to have one man lifting coagulum from the tank and one feeding the machine, but in the other system the one labourer can do both, provided the machining is stopped when each tank is finished and the whole factory staff is set to remove partitions from the next tank and push it into position. This lay-out more readily lends itself to extensions, than does the one using fixed tanks.

For estates having larger crops and requiring from ten to twenty tanks, the scheme shewn in Fig. 2 seems to give the best arrangement. By employing one man to remove partitions, push tanks, and assist the labourer feeding the machine, a fast uniform rate of feed to the battery can be obtained, whereas with fixed tanks and a long central chute an extra man may be required to help push the coagulum from the tank to the battery. Here again the rail system has the same advantages of economy in water, and facility for extensions. It also confines the tank-washing to one bay which helps to keep the factory clean, and enables special water-points and partition tables to be installed for the purpose. In this case, where a fairly long length of rail is required, the design in Fig. 3 does not appear to give such a compact arrangement.

For very large estates where more than thirty tanks are required, two machines become desirable. A satisfactory method of duplicating the arrangement in Fig. 2, under one roof, with only one set of bulkers and one truck line to the smoke-house, has not yet appeared, whereas a very compact design can be evolved using fixed tanks, by duplicating the lay-out shewn in Fig. 1 and running the smoke-house truck-line in a central trough between the two units.

For use in conjunction with continuous sheeting batteries the system using tanks on rails has an undoubted advantage, since the long ribbon of coagulum can be fed straight into the machine; whereas with the fixed tanks the coagulum has to be turned through ninety degrees to enter the chute and may suffer distortion. This difficulty can be reduced by arranging the tanks in

echelon formation at an angle to the central chute. It is important that where the tanks are mounted on trolleys the rails should be very carefully levelled. If this is not done the tanks will be difficult to move and may become badly strained in use.

Bulking Tanks

Bulking tanks are shewn in each type of lay-out. Their original purpose was to remove much of the fine sand and dirt from the diluted latex by sedimentation, and they are therefore designed with a main latex run-off just above the bottom of the tank, so that when the latex has been diluted and allowed to settle for about twenty minutes, it can be removed without disturbing the sludge, which is drained off through a secondary cock. In this way much of the dirt which is too fine to be sieved out of the latex may be removed. The bulking tanks are useful in another respect since they reduce the possibility of variations in the dry-rubber-content of the latex in the coagulating tanks. Provided that the latex and water are well mixed in the bulking tank, each coagulating tank filled from that bulk will contain latex of identical dry-rubber-content. The metrolac, although useful, is not very accurate and there are possibilities of appreciable variations in the coagulum produced if each tank is standardised separately by this means. Apart from the risk of errors in observation, it is probable that the latices from different parts of the estate will differ, due to variation in the age and type of trees, or to the amount of preservative added. Bulking will tend to smooth out these differences and will assist in the preparation of uniform sheet.

Bulking tanks may be constructed of reinforced concrete, steel, or aluminium. It is important that the tanks should have a smooth inner surface which is easily cleaned. Concrete tanks, once placed in position, are permanent, and cannot be altered to suit any factory re-arrangement. The preparation of a good smooth surface is difficult. Tiles have been used, but the joints provide cracks which are impossible to clean. Fairly satisfactory results have been obtained by treating the smoothly-rendered cement surface with sodium silicate solution, followed by a coating of special corrosion-resisting paint. Steel tanks should be welded to give a smooth inner surface, which also needs to be treated with a special paint. Aluminium tanks, although more expensive initially, need no surface treatment and therefore involve no maintenance costs.

Coagulating Tanks

Aluminium-lined coagulating tanks have been largely standardised, and are available in two types, for making either a continuous coagulum or separate sheets. Various depths can be obtained, and the depth of tank employed should be selected according to the machine which is to be used. Some batteries cannot handle successfully a coagulum more than nine inches wide, in which case tanks deeper than twelve or fourteen inches are not required. For convenience in packing, the sheet should be approximately nineteen inches wide when wet. In some smokehouses provision has been made for sheet twenty-two to twenty-four inches wide, and it may be necessary to make sheet of this width in order to take full advantage of the smoking capacity available. Batteries vary to some extent in the width of sheet they will produce from a given width of coagulum, and attention should be paid to this point in selecting the depth of tank to be used. The number of tanks should be sufficient to deal with the maximum crop likely to be obtained, without the necessity of increasing the dry-rubber-content at which coagulation is carried out, or of placing in the tanks more latex than has been found to give the best width of coagulum for the particular machine.

The optimum dry-rubber-content for coagulation also depends upon the type of battery used. One-and-a-half pounds of rubber per gallon is the concentration usually employed, but a light machine working at fairly high speed with only four pairs of rollers may require a lower dilution to produce sufficiently thin sheet without undue strain.

Little need be said with regard to the actual process of coagulation. Economy in the use of acid is desirable, since, apart from the cost of this material, excess acid tends to produce a harder coagulum, which increases the work to be done by the sheeting machine. It is possible, by a systematic routine, to reduce the possibilities of personal errors, which would lead to variations in the sheet. The advantage of the bulking tank in standardising the dilution has already been mentioned, as has the desirability of feeding a standard width of coagulum to the machines. This is achieved by using exactly the same quantity of latex in every tank every day. If this is done, a fixed quantity of acid is always required for each tank. The measurement of a constant quantity of acid offers much less risk of error than the calculation and measurement of varying quantities to suit the different volumes of latex in each tank. In practice the size of the crop varies, and it is therefore necessary to provide an additional tank, of the utility type, or one which has a movable

sealing partition arranged to cut off any desired length of the tank for coagulation.

Sheeting Battery

The sheeting battery is a machine consisting of from four to six pairs of rollers arranged in line-ahead formation, with a common drive. The upper and lower roller of each pair run at the same speed, and the speed of each pair is greater than that of the preceding one in the line. The last pair of rollers is an exception to this, since it is grooved to provide a marking on the sheet, and is run at a lower speed than that of the preceding smooth pair.

A number of machines conforming to this general description, but incorporating special details of design and construction, are manufactured and are sold at competitive prices. The first problem to be decided when selecting a machine is whether continuous coagulum or separate pieces are to be rolled, since, owing to the difference in roll speeds required, the same machine will not work equally well for both purposes. In factories which are being reorganised this will usually be determined by the coagulating tanks already available, but where a complete new equipment is to be installed the choice is often difficult.

On theoretical grounds, the continuous sheeter should give a higher economic efficiency, since the rubber passes through in a long continuous ribbon, whereas when separate sheets are used there is an interval, during which the rolls are running idle, between the end of the sheet and the entry of the next. Thus a machine working on continuous coagulum will usually give a higher output per hour. The difference between the two will depend on the efficiency with which the separate sheets are fed into the machine. For example, a machine which delivers one foot of rolled wet sheet per second will have a theoretical output of 3,600 feet per hour, whereas an average interval of four seconds between sheets which are usually about six feet long will reduce the output to 2,160 feet per hour. An average interval of $1\frac{1}{2}$ seconds between sheets may be considered as very efficient feeding, and $2\frac{1}{2}$ seconds is a good average figure which should be attainable in most factories. It will be noticed that the output is expressed as length of wet sheet per unit time, and that for a given roll-speed the output in terms of weight will depend upon the width and thickness of the wet sheet.

In practice the difference in output between the continuous and separate sheet machines is reduced by using higher roll-speeds on the latter, and the continuous sheeting machine should be

regarded as the one which will give the required output with a lower roll-speed, rather than the one with the higher output per hour. This means that for a given output the machine rolling continuous coagulum will be subject to less wear on the bearings and should consume slightly less power. The slower roll-speed has another advantage, in that the longer time for which the rubber remains in the nip between the rolls ensures a more efficient squeezing action and less recovery after rolling. The slip between the rollers and the coagulum increases with increase of roll-speed, and slip represents a loss of power. There are some disadvantages in the manufacture of continuous coagulum. The difference in the initial cost of the two types of machine is not great, but the special tanks required for continuous coagulum are more expensive. A rather harder coagulum is usually required for continuous working and since this is more difficult to roll out, it will tend to cancel the advantage gained by the more efficient squeezing action of the continuous machines. A machine working on separate pieces of coagulum requires less critical setting and is less sensitive to variations in the coagulum than when the continuous strip is used.

The final consideration is the labour required for working each type of machine. If continuous coagulum is used, there is no necessity for a labourer between each pair of rollers, but the handling of the wet sheet as it leaves the rollers is more difficult, since twice as much cutting is required for each tank of coagulum. In order to reduce the handling of wet sheet to a minimum it is advisable to cut the sheet and hang it on the smoke-house trolleys as it is delivered from the machine. With the continuous sheeting battery working at a fairly high rate of output, three labourers will be required to carry and hang the rubber, while a skilled labourer is required to cut the sheet. In many cases this method is not attempted, but the sheet is cut into pieces six feet long and piled until the machine is stopped. The piles of rubber are then cut through and the sheet is hung. It frequently happens that in the cutting the sheet becomes massed together and time and energy are wasted in separating it again before hanging, so that if manufacturing time is reckoned from the time at which machining is started until the rubber is on the trucks, the machine operating on continuous coagulum by this method may not compare favourably in output per hour with one using separate pieces. In considering the labour required it is necessary to regard the process as a whole rather than stage by stage. Labour is required for sorting and packing, and for cleaning the coagulating tanks, and it may prove more economical to bring the packing shed staff into the factory while the machining is in

progress, and allow the factory staff to help in the packing shed later, than to keep the two staffs separate, and try to reduce the number of labourers in the factory to a bare minimum.

Machines can be obtained with from four to six pairs of rolls, and with machines in which each pair has to be fed separately the tendency is to use the minimum number of pairs in order to save labour. Usually, however, better results will be obtained by using a larger machine, which is better able to deal with variations in coagulum and small inaccuracies in roller setting, and will be less heavily stressed in operation.

In the foregoing comparison, the machines working on separate sheet have been assumed to be of the type in which the pairs of rollers are a considerable distance apart, and which require a separate labourer to feed each pair of rolls. There is, however, one type of machine available for rolling separate sheets in which the pairs of rollers are placed close together and in which an automatic feed is obtained from one pair to the next by means of an ingenious patented chute. This, like the continuous machine, avoids the necessity for a labourer between each pair of rolls and the next, and, at the same time does not require the more expensive continuous tanks, nor involve the difficulty in cutting the rubber.

On large estates maximum economy will usually be attained by working at high machine outputs since this will avoid the necessity of duplicating the machinery. On small estates, smaller and cheaper machinery with a slower rate of working will often give equally good results while requiring less close supervision, and a lower initial outlay. The machines should normally be set to deliver wet sheet between one-tenth and one-eighth of an inch thick, and if it is required to increase the output, attention should be paid to increasing the width of the wet sheet and, where separate sheets are used, the efficiency of feeding, before any attempt is made to increase the roll-speeds, since excessive speed leads to slip and tearing of the sheet. The machines should be so set that each pair of rollers plays its part in compressing the rubber. If the coagulum is uniform the rollers may be left for long periods once the gap has been set, but variable coagulum will require frequent readjustment of the rollers for the best results. In feeding the rollers a uniform rate should be the ideal to aim at. It is not uncommon to find, when changing over from one tank to the next, that there is a temporary hold-up in the supply of coagulum, after which a number of pieces reach the feeding end of the battery in quick succession, and the labourer at this point is tempted to pass them into the machine too rapidly, causing doubled-over corners and folds in the sheet. A reasonably fast even rate of working will give far better results than

a series of quick rushes and temporary lulls. Labourers should therefore be trained to this end, and a pace set which they can maintain without fatigue for several hours.

Owing to the variations in weather, seasonal effects, the change-over of fields in tapping etc., it will never be possible to obtain perfectly uniform wet sheet, but attention to the various details of procedure outlined above will do much to reduce the variations to a minimum.

Drying

It is not proposed to discuss here the theory of drying nor the construction of any particular type of smoke-house, since considerable space has been devoted to these matters in an earlier issue of this *Journal*[1]. Attention will be confined to a few practical points which are applicable to all types of smoke-house.

As was mentioned earlier, sheet-thickness and temperature are the major factors controlling the rate of drying. The latter is limited by the risk of damaging the rubber, and it is advisable to leave a reasonable safety margin below this limit, since close temperature control is impossible where direct wood firing is employed. Much however can be done by training the labourer to maintain a steady fire and to add small quantities of wood frequently, rather than large quantities at long intervals. A maximum and minimum thermometer is usually the only check available on the conditions inside the smoke-house. This is not entirely satisfactory, since no record is obtained of the time during which the temperature has been maintained at any particular level between the two limits. A thermograph is the only satisfactory instrument for this purpose. The ordinary maximum and minimum thermometer will, however, give more information than is sometimes realised, if it is used carefully and attention is paid to the minimum as well as to the maximum reading. The thermometer is frequently reset when the chamber is opened up for the introduction of a fresh charge of rubber, and in this case the minimum reading tells only the outside air temperature. The thermometer should be set after the smoking chamber has warmed up to its normal working temperature, and should be read again, before the smoke-house is opened next morning. In this way it is possible to tell from the minimum reading whether the smoke-house labourer has allowed the temperature to fall unduly during the night. The position of the thermometer should be selected with care since many smoke-houses have small "dead" spots in which the temperature is considerably different from that in the rest of the house, and a

thermometer placed in one of these spots will not give an accurate reading.

The minimum temperature is particularly important in the early stages of drying, when the rubber is losing water very rapidly, for unless an abnormally high rate of ventilation is employed the air in the drying chamber will be nearly saturated, and a sudden slight fall in temperature will cause the deposition of dew. For example, air which is only 80 per cent. saturated at 105°F. will be on the point of depositing moisture at 98°F. Thus to avoid condensation in the smoke-house it is necessary to keep the minimum temperature as close as possible to the working temperature decided upon. If the trouble persists in spite of close temperature control, it will be necessary to increase the air flow through the chamber. This however will increase the fuel consumption required to maintain the working temperature and will also tend to dilute the smoke.

With regard to sheet thickness, the only point which it is desired to emphasise is that the day's crop is not dry until the thickest part of it is dry. The ideal condition would be realised if the whole crop became dry at the same time. This cannot be realised in practice, but with uniform coagulum, evenly-set machines carefully operated, and a well-designed smoke-house in which cold pockets are avoided, reasonable uniformity in drying rate can be achieved. The avoidence of variations between one day's crop and the next is as important as uniformity throughout the sheet manufactured in any one day. For efficient economic drying the smoke-house ventilation and firing need fairly critical setting, and it is a matter of experiment in each particular case to find the best conditions. Once found it is possible to train a labourer to maintain those conditions fairly accurately. It is not however possible to state off-hand what alterations in ventilation and firing will be required to allow for an alteration in the supply of wet sheet; and it is therefore futile to expect the labourer to adjust his operation of the smoke-house to accommodate variations in the sheet.

Packing

Comparatively little attention has been devoted to the organisation of packing, which remains a slow and rather costly part of the process. The only mechanical aids which would be of practical value would be hydraulic presses, and mechanical conveyors and stackers. These machines are expensive and it is unlikely that the scale of operations in an estate rubber factory will justify the cost of such equipment. Failing such devices a fairly high degree

of efficiency can be obtained by planing the packing shed so that the rubber follows a short straight-line course from the smoke-house via the sorting bench, weighing machine, and press to the storage bay. Carrying of sheets, and piling, with the subsequent necessity for separating it again, should be reduced to a minimum. The careful selection and training of labour for sorting and clipping appears to offer the greatest scope for economies in the packing shed. It appears that it would be as easy for a sorter to fold the clipped sheet and drop it into a case as to spread it carefully on a pile, which is later carried away, separated and folded, yet this method has not yet been observed in practice. In this problem it appears that a careful study of working conditions, lighting, and even motion study, offers a more profitable line for research than attempts at mechanisation.

Summary

In the foregoing paper an attempt has been made to set out some of the factors which need consideration in the design of an estate rubber factory and selection of equipment for the manufacture of smoke sheet. Attention has also been drawn to a number of details of operation which are regarded as important at the present time, since it is believed that improvements and economies in the immediate future will be effected by attempts to make the best use of existing types of equipment rather than by violent departures from current designs. The speed of the manufacturing process is that of its slowest part, and efficiency will be lost rather than gained, by accelerating one stage at the expense of others. A smooth, even production will give the greatest economy and will be the most easily operated.

Reference

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Kuala Lumpur,

19th November, 1937

THE CONSTITUENTS OF HEVEA LATEX

PART II

SEASONAL VARIATIONS IN THE COMPOSITION OF TYPICAL SEEDLING LATEX

BY

K. C. ROBERTS

Introduction

The problem of the variability of latex and of plantation rubber has hitherto been approached mainly from the point of view of field and factory practice. Absence of standardised procedure and of clean technique in the handling of latex and the manufacture of raw rubber clearly tends to the production of a non-uniform product. But despite all advances in this direction, consumers continue to report considerable variations in the physical properties of latex ammoniated for export and of raw rubber, and in the behaviour of the latter on vulcanisation.

It is now apparent that considerable variation is inherent in latex itself and is presumably determined by such factors as climate, genetic strain of the tree, type of soil and topography. Attention is therefore now being directed towards tracing by analytical means, variations in the composition of latex (and therefore of raw rubber) which have their origin in such factors. The work of Wiltshire (1) in this field covered a 12-month period, and dealt with variations in the dry-rubber-content and the inorganic constituents of latex.

Scope of Present Work

The present paper describes the results of observations covering a similar period, June 1936—May 1937 inclusive, and deals with the variations, qualitative and quantitative, of all the known naturally-occurring constituents of latex. The method of analysis used has been that described in Part I of this series (2), and the observations therefore deal with the Ammonium Salt, the Ester, the Fatty Acid Complex, the Phosphate Complex*, Crude Caoutchol*, and the Rubber Hydrocarbon itself. Throughout the

* The constituents now named "Phosphate Complex" and "Crude Caoutchol" correspond to the "Protein Complex" and the "Sulphur Complex" of Part I. These changes have become necessary in the light of further knowledge of the nature of these constituents. Nitrogenous matter is less characteristic of the "Protein Complex" than its phosphate material, while the most characteristic feature of the former "Sulphur Complex" is not so much its sulphur content, as a new alcoholic component, which has been named Caoutchol. A detailed account of this will appear in the near future.

period, fresh latex from an estate in the neighbourhood of the Institute has been subjected to analysis as frequently as circumstances permitted, *i.e.* on an average 5-6 times per month. At the same time records have been kept of rainfall, incidence of wintering, region of estate from which the latex was drawn, and variations in tapping practice. The effect of the last-mentioned, controllable factor on the composition of latex will be discussed in a later communication.

Results

"Ammonium Salt"

This constituent was obtained during the 12-month period in forms ranging from a colourless crystalline solid (*cf.* Plate IA) to a brown gummy material. It varied widely in amount (*cf.* Table I), but the amount was at most only small. For this reason, and also because it is frequently associated with a considerable proportion of quebrachitol (*cf.* (2) p. 49), no particular signficance may be attached to this variation. Variations in both quality and quantity were frequent and irregular, and no correlation has been established between them and any other factor. It may however be remarked that the amounts isolated tended to be low for several months (June—December inclusive) during which the rainfall was below the average for that period (*cf.* heavy black line, Graph 2).

It is believed that this material consists essentially of a relatively simple substance which is rapidly used and renewed by the tree in the synthesis of more complex bodies.

"Ester"

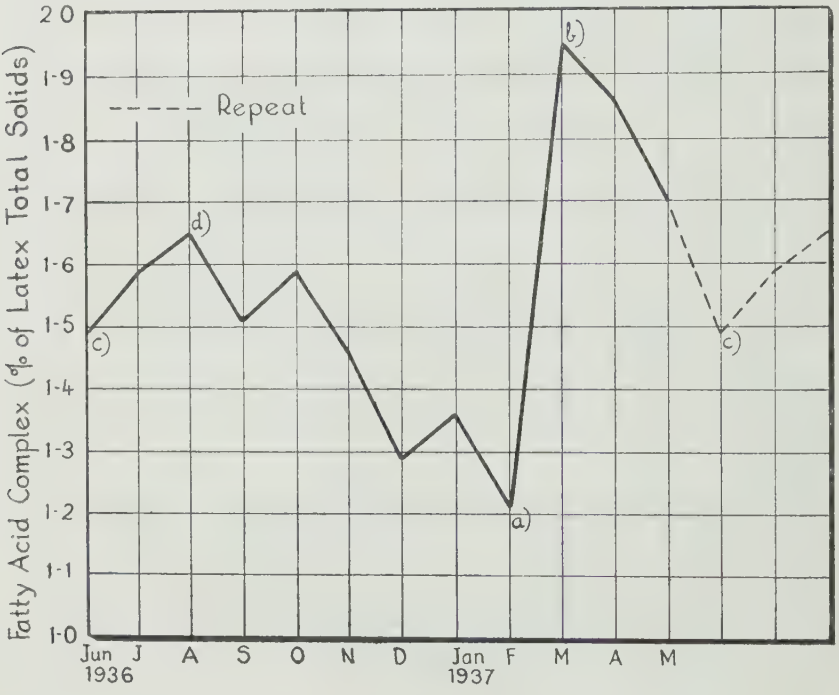
This constituent, the ligroin-insoluble portion of the acetone-soluble matter, was observed at various times as a red oil, a wax-like solid, and a coarsely crystalline mass. The last-mentioned occurrence was due to the inclusion of a considerable proportion of quebrachitol. Quantitative variations closely followed those of the "ammonium salt" (*cf.* Table I).

TABLE I

Constituent	Per cent of Latex Total Solids			
	Lowest Value	Highest Value	Mean	No. of Specimens
"Ammonium Salt" ...	0.01	0.23	0.06	55
"Ester"	0.04	0.26	0.12	49
Fatty Acid Complex ...	1.11	2.46	1.58	64
Crude Caoutchol	1.25	4.66	2.39	62
Phosphate Complex ...	3.54	6.23	4.90	42
Crude Hydrocarbon ...	84.70	93.70	88.97	39

Fatty Acid Complex

Qualitatively, this constituent showed but little variation throughout the period of observation. It ranged from a deep yellow to a dark-red oil, which in all cases deposited crystals when kept, (Plate IB) though with varying degrees of facility. The quantitative range is shown in Table I. Since the complex is a constituent of a biological fluid, a considerable variation such as that observed is not surprising. In view of the familiar use of the fatty acids as softeners of rubber, the observed variation is almost certainly large enough to be significant from the point of view of variability in the physical properties of raw rubber.



Graph I

Monthly Average Values for the Amount of Fatty Acid Complex.

The factor chiefly responsible for quantitative variations in the fatty acid complex appears to be the incidence of wintering. Reference to Graph I shows a pronounced minimum value (a) for February, when wintering was in progress. This point is followed immediately by an equally pronounced maximum (b) in March and a further high value for April, these two months corresponding to the period of maximum refoliation activity. Thereafter the curve drops to a secondary minimum in June (c) which precedes a rise to a secondary maximum (d). It is perhaps

significant that these subsidiary features coincide with the period of seed development in the tree (June to August). Other irregularities in the curve are too small to be significant.

Crude Caoutchol

This constituent varied widely in texture from specimen to specimen. During the period under review specimens were observed ranging from a dark-brown, tacky, semi-fluid mass to a light-brown, non-tacky elastic solid. The variation in amount recorded in Table I (1.25 to 4.66 per cent. of latex total solids) is notable, and can scarcely fail to be of critical importance in determining the properties of latex and rubber. This is particularly the case since it has been found that the rubber hydrocarbon purified by removal of caoutchol is almost devoid of elasticity. The plasticity and vulcanisation tests necessary to establish a correlation between caoutchol content and the properties of rubber will be undertaken in this laboratory in the near future.

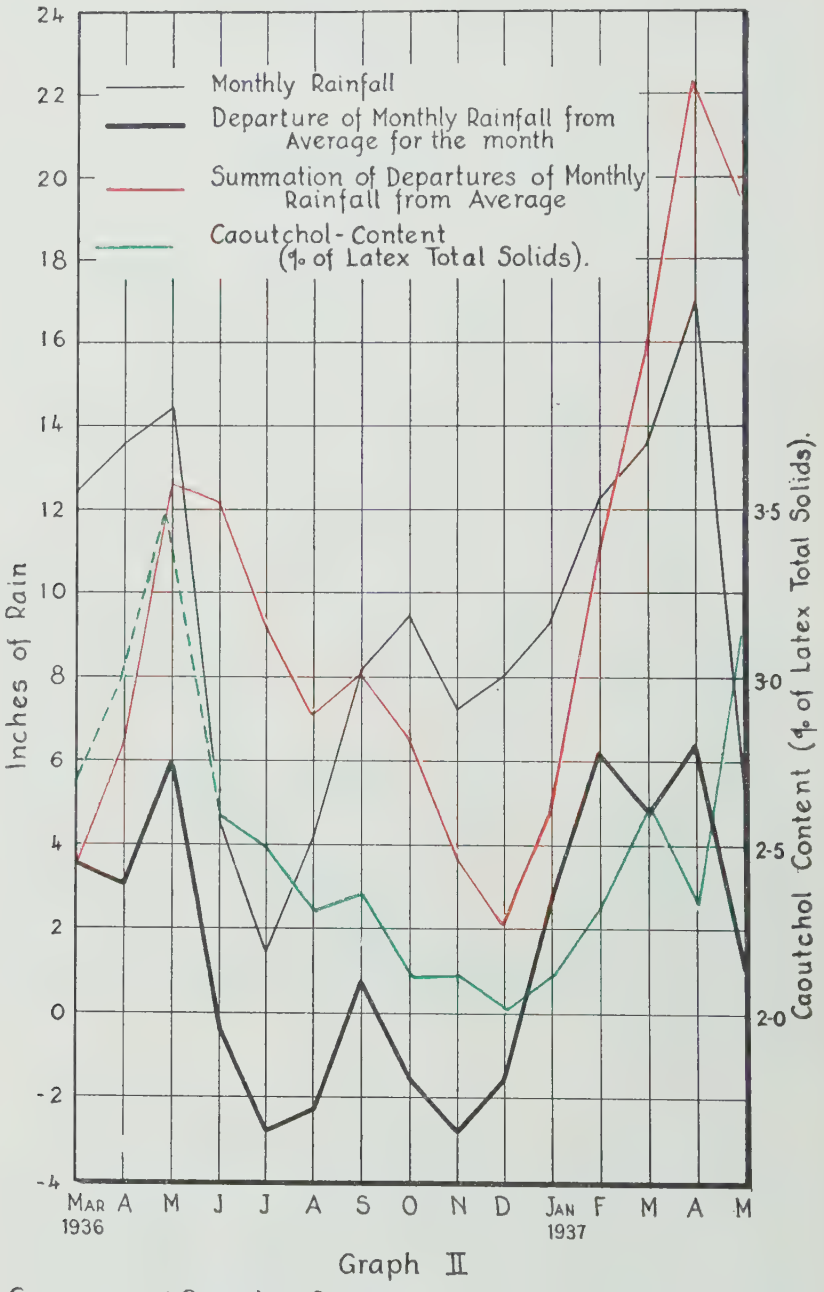
Although no final conclusion has yet been drawn as to the causes of the variation in nature and amount of caoutchol, there does seem to be a connection between the amount of caoutchol and the rainfall. This is revealed by a comparison of the monthly average values of the amounts of the constituent with the rainfall statistics, as shown in Graph II.

The periods of high rainfall (March-May 1936; January-April 1937) are seen to be accompanied by a rising tendency in the curve representing monthly average amounts of caoutchol (green line), while the period June—December 1936, during which the accumulated deficiency of rainfall was more than 10 inches, is accompanied by a falling tendency in the caoutchol-curve. Supplementary data obtained prior to June 1936 are indicated by the dotted section of the caoutchol-curve. There is no indication of any relationship between the caoutchol-content of latex and the wintering period.

Phosphate Complex

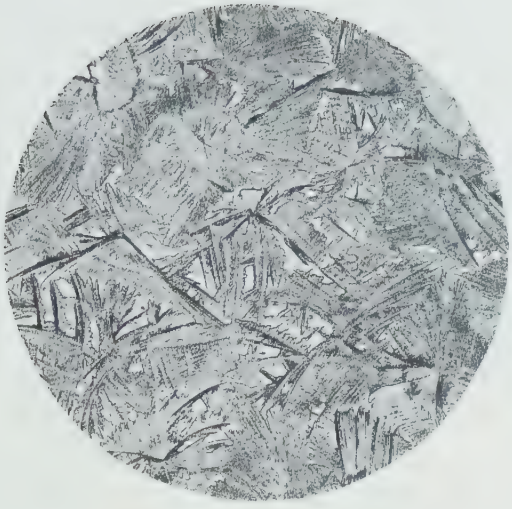
No variations in chemical or physical character of this constituent from specimen to specimen were detected during the 12-month period. Samples invariably consisted of an amber-coloured, pleasant-smelling, glassy material which took up water and formed large crystalline plates (*cf.* Plate IC) when kept in the open air.

The extreme range of amounts of the complex (3.54—6.23 per cent. of latex total solids) is considerable, but of the 42 specimens prepared, only three lay outside the range 4.0—6.0 per cent. It may therefore be stated that, for a component of a biological fluid,



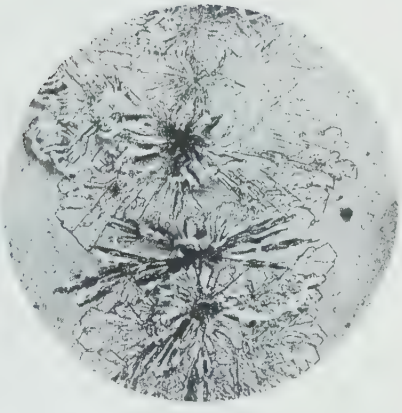
Graph II

Comparison of Caoutchol-Content of Latex with Rainfall



A

B

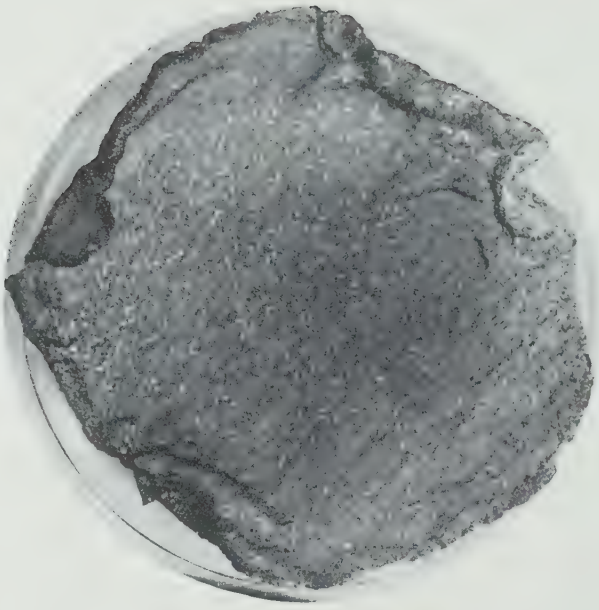


C

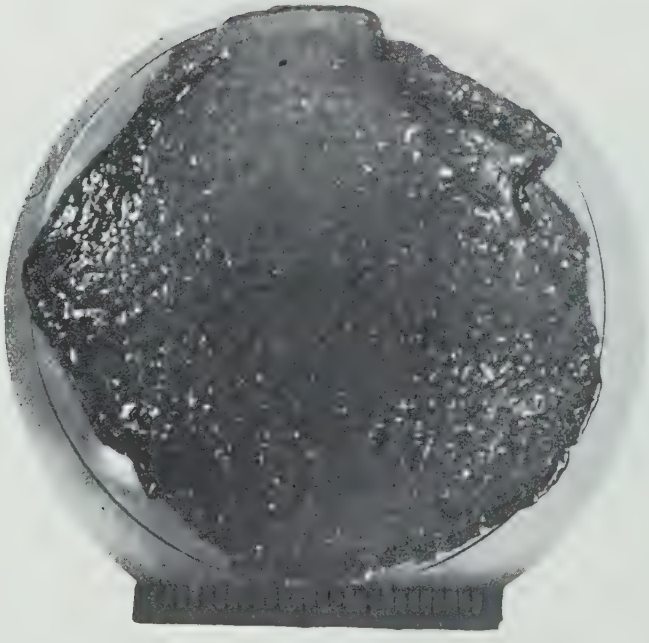
A "Ammonium Salt" × 18

B Fatty Acid Complex × 18

C Phosphate Complex × 18



A



B

A. Rubber hydrocarbon, freshly prepared.
B. „ „ , kept 4 weeks.

the phosphate complex shows a considerable degree of uniformity both in character and in amount. Such variation as has been observed does not appear to be dependent on any of the factors considered.

The Crude Rubber Hydrocarbon

The specimens of this material prepared during the analyses were very uniform in character, being all plastic, amber-coloured materials (*cf.* Plate II A & B) having very slight elasticity and varying degrees of tackiness. Since the amounts of all constituents are expressed as percentages of the total solids of latex, the variation in amount of the hydrocarbon is naturally a reflection of the varying amounts of the non-hydrocarbon constituents. No evidence has been obtained that the properties of plantation rubber are dependent on the water-content of latex.

Discussion

At the outset it is emphasized that the above is to be regarded as a preliminary study of this complex and important subject. It will be appreciated that it is very difficult to form conclusions from a study of analytical results which are liable to be influenced by a considerable number of variables. At the commencement of this work it was realised that under the best conditions then available it would be impossible to avoid possible variation due to the drawing of the latex from an area of several hundred acres. This involved taking specimens from a wide range of soil and tree types, and from land having a varied topography. Also, with Malaya's heavy and very unevenly distributed rainfall, accurate correlation of analytical results with rainfall over such a large area was out of the question.

But in addition to the above possible sources of variation owing to other than seasonal causes, a number of other abnormal factors have been unavoidably introduced. These are enumerated below.

(i) The period chosen has proved to be a phenomenal one climatically. A succession of months (February—May 1936 inclusive) in which the rainfall greatly exceeded the average for those months (the accumulated excess rainfall was 13.96 inches), was followed by a period of seven months during which, with one exception, rainfall below the average for those months was recorded. The accumulated deficiency during this period was 10.54 inches (*cf.* Graph II). The ensuing four months, on the other hand, were all unusually wet, the accumulated excess rainfall for this period being no less than 20.22 inches. Such conditions

are without parallel in the records of the past twelve years, and naturally cannot be expected to reflect the normal variability of the composition of latex. They have however had the advantage of revealing a relation between rainfall and latex composition which would otherwise have been less obvious (*cf.* Graph II).

(ii) The selection of the estate from which to draw latex samples, necessarily restricted by the need for obtaining specimens fresh from the field, has from the present point of view been unfortunate. The tapping system has been changed from time to time, and the analyses discussed represent samples drawn on daily, third-daily and fourth-daily tapping systems. Further, from the above and other untraced causes, the dry-rubber-content of latex samples dealt with has shown an extraordinarily wide variation (from 28.8 to 47.5 per cent.). Although this is disconcerting from the point of view of this investigation, no evidence has been obtained that the composition of the total solids is dependent on the water-content of latex.

(iii) Finally, the fire which practically destroyed the Chemical Division of the Institute caused considerable dislocation of certain aspects of the work for some time. A further investigation under conditions eliminating all variations of external factors except the climatic is in progress. The results to date confirm the above findings.

Conclusions

The investigation reveals that certain latex constituents are subject to wide variations both in quality and in quantity, and that these variations are either inherent in the tree or are caused by external factors, chiefly rainfall, wintering and refoliation, over which the producer has no control. The results of investigations of the effects on latex composition of the controllable factors, tapping system and genetic strain of the tree, will be reported in due course.

The observed variations in amount of two of the major non-caoutchouc constituents, *viz.* the fatty acid complex and crude caoutchol, are judged to be large enough to cause variations in the physical and mechanical properties of plantation rubber. Variations of the phosphate complex on the other hand appear unlikely to be significant from this point of view. The large variations shown by the minor constituents, "ammonium salt" and "ester" are probably without technical interest, but it is suggested that they are closely associated with latex metabolism.

Summary

(i) During a 12-month period, latex from a particular estate has been analysed, as frequently as circumstances permitted, by the method already described (2).

(ii) All constituents show considerable and almost daily variations, which in the cases of the fatty acid complex and crude caoutchol are judged large enough to be of technical significance.

(iii) In addition to the daily variations, two seasonal changes have been detected. In the first place, monthly average values of the amount of fatty acid complex reached a minimum during the wintering period, and rose immediately afterwards to a maximum coincident with refoliation. Secondly, monthly average values of the amount of crude caoutchol showed a rising or a falling tendency according as the rainfall was abnormally high or low over extended periods. These findings are receiving confirmation from a further series of observations made under the more rigorously controlled conditions now possible.

Acknowledgment

I am indebted to Mr. Hoh Choo Chuan for assistance in the preparation of the plates and diagrams.

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(1) Wiltshire, J.L., Rubber Research Institute of Malaya, *Bulletin* No. 5.

(2) Roberts, K.C., This *Journal* **7** (1936) 46

Kuala Lumpur,

26th November, 1937.

THE CONSTITUENTS OF HEVEA LATEX

PART III

ANALYSES OF PLANTATION RUBBER AND OF CREAMED LATICES

BY

K. C. Roberts

Introduction

The method of analysis of fresh latex described in Part I of this series (1) has been applied with only slight modifications to a variety of types of plantation rubber and creamed latex. It is also applicable to ammoniated latex, but since the composition of this product presents numerous special features, it is discussed in a separate paper, Part IV, which follows immediately.

Procedure

Rubbers

The finely-divided dried sample (30 g.) was added to a mixture of carbon tetrachloride (700 cc.) and acetone (450 cc.), and intermittently stirred until a homogeneous dispersion resulted. The remaining operations were carried out in the usual way.

Creamed Latices

The cream was diluted with water to a rubber-content of approximately 30 per cent., and the total-solids-content of the product was determined. Fifty cubic centimetres of this liquid were dried on each of two of the standardised plate-glass frames, and the resulting film was treated in the normal manner.

Results

Tables I and II summarise analyses of a variety of typical samples of plantation rubber and creamed latex. The limits of the amounts of each constituent found in fresh latex to date are included in Table II for comparison. All findings are expressed as percentages of total solids.

TABLE I

Composition of Various Types of Plantation Rubber

Constituent	Smoked Sheet	Pale Crepe	Water-white Crepe	Air-dried Sheet	Crepe from Centrifuged Concentrate
"Ammonium Salt" ...	0.004*	0.004	0.03	0.15	
"Ester"	0.08*	0.07	0.09	0.50	1.24
Fatty Acid Complex ...	1.53*	1.89	1.75	2.46	
Crude Caoutchol ...	3.50	2.07	3.23	3.82	2.29
Phosphate Complex ...	0.20	0.38	0.24	0.22	0.36
Hydrocarbon	94.20	95.20	94.04	92.23	—
Total ...	99.514	99.614	99.38	99.38	—

TABLE II

Composition of Various Types of Creamed Latex

Constituent	Triple-Centrifuged Cream	Tragon Seed Cream	Konnyaku Cream	"Synthetic" Cream	(Fresh Latex)
"Ammonium Salt" ...	0.12	0.09	0.12	1.88*	0.00-0.23
"Ester"	0.28	0.36	0.18	0.43*	0.04-0.60
Fatty Acid Complex ...	1.49	1.59	1.97	2.01*	1.11-2.46
Crude Caoutchol ...	4.40	3.90	3.96	3.47	1.25-4.66
Phosphate Complex ...	0.63	0.74	1.20	1.31	3.54-6.23
Hydrocarbon	—	92.12	91.89	—	84.7-93.7
Total ...	—	98.80	99.32	—	—

Discussion

(i) All the constituents of fresh latex occur in each of the above products derived from it. The figures with asterisks

represent constituents which consist in part of foreign matter acquired in the process of preparation.

(ii) Of the non-hydrocarbon constituents, the phosphate complex alone shows values which lie outside the limits observed for fresh latex (the special case of the "Ammonium Salt" of the "Synthetic" creamed concentrate is discussed below).

(iii) The amounts of the water-soluble phosphate complex are all considerably lower than those found for fresh latex. This is the natural consequences of the fact that the "serum solids" which constitute the bulk of the phosphate complex are, to a large extent, removed in the sera during the preparation of all the above specimens.

(iv) It is noteworthy that the "ammonium salt", although water-soluble, nevertheless appears in normal amounts. It must therefore be associated in latex with another constituent in such a way as to be retained by the rubber-phase during the preparation of raw rubbers and creamed latices.

Smoked Sheet

The "ammonium salt" of smoked sheet includes a small amount of a simple phenol (guaiacol or a cresol) derived from the smoke. It was detected by its odour and by the development of a green colour with ferric chloride. More complex phenolic bodies from the smoke, similarly detectable, occur in the "ester" and the fatty acid complex. The caoutchol isolated was unusually tacky, the hydrocarbon was normal.

Pale Crepe and Air-Dried Sheet

Apart from their low content of phosphate complex, these materials provided components indistinguishable from those of fresh latex.

"Water-white" Crepe

The analysis closely resembles that of pale crepe. This observation is of particular interest, since this superfine grade of crepe is prepared by a process of fractional coagulation, which might be expected to remove, at least partially, certain of the major non-hydrocarbon constituents. It was noticed however that all the constituents isolated were unusually light in colour.

Crepe from Centrifuged Concentrate

This specimen of crepe was prepared by coagulation of the diluted ammoniacal concentrate with magnesium silicofluoride, and

soaking of the resulting coagulum before machining. It was less readily soluble in benzene and in carbon tetrachloride than normal rubber, and remained incompletely dispersed by the usual carbon tetrachloride-acetone mixture even after 72 hours. The caoutchol isolated was very tacky, while the hydrocarbon was not easily soluble in rubber solvents. These are characteristic features of all rubber derived from ammoniated latex, and are discussed in the ensuing paper.

Triple-Centrifuged and Tragon-seed Creamed Concentrates

Quantitatively, these materials present no unusual features. The drastic washing action involved in their preparation resulted in the isolation of unusually light-coloured non-hydrocarbon constituents. The effect of ammoniation was seen in the tacky texture of the crude caoutchol and in the increased resistance to solvents of the hydrocarbon.

Konnyaku-Creamed Concentrate

The analysis of a cream prepared by addition of Japanese Konnyaku meal to ammoniated latex presented no additional features.

"Synthetic" Creamed Concentrate

The creaming agent used in the preparation of this material was a proprietary substance, appreciably soluble both in water and in acetone. It is used in much larger quantities than the above two vegetable creamers, and appreciable quantities of it are therefore retained in the concentrate. Its solubilities caused it to appear among the non-hydrocarbon constituents as shown in Table II*. The characteristics of the caoutchol and hydrocarbon fractions corresponded with the fact that no ammonia was used in the creaming process; that is, they resembled the corresponding products from fresh latex.

Summary

(i) The method described in Part I of this series (1) for the quantitative separation of the constituents of fresh latex has been applied to plantation rubber and creamed latices.

(ii) Quantitatively, the water-soluble phosphate complex alone among the constituents of raw rubber and creamed latices differs from the values found for fresh latex. The low values observed for this constituent reflect the removal of the "serum solids" in the different processes of preparation.

(iii) Qualitative differences from the constituents of fresh latex are of two kinds only:

(a) those due to the occasional inclusion of foreign matter introduced during manufacture;

(b) those due to chemical changes produced in certain constituents by the action of ammonia.

This subject is developed in the ensuing paper.

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Kuala Lumpur,

26th November, 1937

THE CONSTITUENTS OF HEVEA LATEX

PART IV

THE EFFECT OF AMMONIATION ON LATEX

BY

K. C. ROBERTS

It is widely recognised that the preservation of Hevea latex with ammonia produces profound changes, but up to the present time investigation of the ammoniated product has been very largely restricted to observations of its physical properties—viscosity, surface-tension, electrical conductivity, hydrogen ion-concentration, and so on (1).

There are two reasons for the lack of chemical studies. In the first place, the absence of a method for the isolation of the individual constituents, has rendered it impossible to correlate differences in the physical properties of latex with changes in any particular constituent; in the second place, fresh latex is, in the nature of things, not available in the laboratories of North America and Europe, with the consequence that comparison of the characteristics of fresh and preserved specimens *of the same latex* is not possible there. The first point has now been met by the development of the method of analysis described in Part I of this series (2), and the second, by applying the method to the study of ammoniated latex in one of the countries of production. An exhaustive comparative study of fresh and ammoniated latices from the point of view of acetone-extract, acid-value, surface-tension, viscosity and stability is now being made in these laboratories by Dr. E. Rhodes. This investigation should prove complementary to the present work.

Latex preserved by addition of 0.7 per cent. by weight of gaseous ammonia may be prepared for analysis in almost the same way as fresh latex. Owing to the reduced viscosity of the treated material, a volume of only 50 cc. (instead of 100 cc. as for fresh latex) is distributed over each of the plate-glass frames preparatory to drying as usual. A slight modification of the analytical procedure is necessitated by the lowered solubility of rubber from ammoniated latex. The dispersion of the dried material in the carbon tetrachloride-acetone mixture is incomplete in the period of 24 hours which amply suffices for the total solid matter of fresh latex, and in order to ensure complete removal of

soluble non-hydrocarbon constituents by the dispersing medium, the mixture is kept before further treatment for a period of days depending on the age of the latex. Even so, the ammoniated product, though finely disintegrated, remains on occasion incompletely dispersed.

Ammoniated latices examined have been of two types—ammoniated estate latices which had been stored for some months in metal drums treated internally to prevent discoloration of the latex, and laboratory specimens kept in glass vessels after ammoniation. The latter thus differed from the former in being exposed to the action of light. No evidence has, however, appeared that diffuse daylight itself has any effect on the latex constituents. Only with the laboratory specimens has it been possible to compare analyses with those of the same latex before preservation. Typical results are summarised in the Table below. In all the preserved samples the ammonia-content was approximately 0.7 per cent. by weight of the latex.

Ammoniation produces such extensive changes in the majority of the constituents that the usual nomenclature becomes inapplicable, and it has been necessary to describe the materials isolated in more general terms. Thus the "fatty acid complex" is in the present connection called "ligroin-soluble matter;" crude caoutchol becomes "acetone-insoluble non-caoutchouc matter" and the phosphate complex, "water-soluble matter." The major constituent, isolable in a less pure form than from fresh latex, is called the "crude hydrocarbon."

Quantitative changes resulting from ammoniation do not appear to have any particular significance in the case of "ammonium salt," "ester" and ligroin-soluble matter. The increase in amount of acetone-insoluble non-caoutchouc matter and the decrease in amount of water-soluble matter are however notable, and have been repeatedly observed.

The only constituents which are not profoundly changed qualitatively by ammoniation are the two minor ones, "ammonium salt" and "ester."

The *fatty acid complex* of fresh latex, composed of a considerable number of alcoholic and acidic substances in chemical combination, is extensively hydrolysed under the conditions of ammoniation, and is isolable as a corresponding ligroin-soluble mixture of the individual constituents of the original complex, *viz.*, alcohols, aliphatic acids, glucoside and terpenic material. This has been established by comparing the behaviour of the two types of ligroin-soluble matter under the action of alcoholic caustic soda.

TABLE

Constituent	Laboratory Specimens			Commercial Latex. Ammoniated 18 months
	Fresh	Ammoniated (No. of weeks in brackets)		
"Ammonium Salt" ...	0.09	0.09	(8)	
+ "Ester"	0.30	0.36	(4)	0.42
		0.24	(14)	
Ligroin-soluble matter ...	1.13	1.12	(8)	
	1.76	1.81	(8)	1.41
		1.73	(18)	
Acetone-insoluble	2.54	7.25	(8)	7.42
non-caoutchouc matter ...	3.10	7.07	(18)	
Water-soluble matter ...	5.58	3.93	(4)	
		3.53	(8)	3.22
		3.22	(18)	

The *phosphate complex* suffers a similar change. The naturally-occurring material contains, among other things, mineral phosphates, a reducing sugar and quebrachitol, but owing to their state of combination, it does not give characteristic reactions for these components. The corresponding "water-soluble matter" from ammoniated latex, on the other hand, gives reactions for all three.

The *crude caoutchol* of fresh latex is in general an elastic body; the corresponding "acetone-insoluble" component of ammoniated latex however is invariably a highly viscous fluid, extremely tacky and possessing no elasticity.

The *hydrocarbon* constituent also undergoes a fundamental change during ammoniation. The hydrocarbon isolated from ammoniated latex showed a much greater resistance to solvent action than either raw rubber or the hydrocarbon from fresh latex.

The above extensive changes in the character of the major constituents of latex under the action of dilute aqueous ammonia are effected within a period of eight weeks, and will thus be far advanced before ammoniated latex reaches the consumer.

The most critical changes from the point of view of the properties of rubber are undoubtedly those involving the caoutchol and the hydrocarbon constituents. Specimens of these materials, isolated from fresh latex in their naturally-occurring forms, have

accordingly been independently subjected to the action of dilute aqueous ammonia, with a view to elucidating the nature of the changes.

Crude caoutchol (20 g.) isolated from 2 litres of fresh latex, was added in the form of a thin sheet to distilled water (2 litres) containing 0.7 per cent. by weight of ammonia, and the mixture was kept for eight weeks, with intermittent shaking. In this way the concentrations and storage period for typical commercial ammoniated latex were closely imitated. At the end of the period, the aqueous liquor remained clear, but had become yellow. From it was isolated a small amount of a complex mixture of organic acids, including the sulphur-containing constituent of crude caoutchol mentioned in Part I (2). It is concluded that dilute ammonia exerts a hydrolytic action on crude caoutchol. The insoluble portion of the reaction mixture had during eight weeks become opaque, cream-coloured and spongy by absorption of the medium. After being washed with water, milled, and dried *in vacuo*, it was a tough, translucent material *insoluble in ether and only very slowly dissolved by the usual rubber solvents*—behaviour very different from that of the untreated substance. Caoutchol so modified will necessarily be retained by the hydrocarbon on analysis. The change is apparently one of polymerisation.

The hydrocarbon from fresh latex, treated in a manner similar to the above, likewise became a soft opaque mass, but no portion of it was dissolved by the ammoniacal medium. The washed product, milled to a thin sheet and dried *in vacuo*, was a tacky, light-brown material which was only slightly dissolved in 3-4 hours by the usual rubber solvents. The undissolved portion slowly swelled in the solvents, but even after 24 hours it remained largely undissolved by benzene, carbon bisulphide, ether and ligroin. A higher degree of dispersion was observed in chloroform, carbon tetrachloride and toluene, but in these media also, solution was incomplete. The untreated hydrocarbon on the other hand dissolves readily with but little swelling. It is suggested that the soluble portion of the treated hydrocarbon is a disaggregated form, which, being more soluble than the normal form, is retained by the carbon tetrachloride—acetone mixture during the analysis and appears as the "acetone-insoluble matter" in place of caoutchol. The insoluble portion, which constitutes the bulk of the treated product, appears to be a polymer of the naturally-occurring hydrocarbon.

These relationships throw light on the apparent loss of water-soluble matter indicated in the Table. The procedure which suffices for the quantitative removal of water-soluble matter from the total solids of fresh latex, is inefficient when applied to the

ammoniated product. An appreciable amount of inorganic matter is retained, along with modified caoutchol, by the "crude hydrocarbon," and may be readily detected as ash.

Summary

(i) Comparative analyses of fresh and ammoniated latices have been made, and the constituents investigated.

(ii) The changes effected by ammoniation are profound, and are far advanced in a period of eight weeks. The minor constituents "ammonium salt" and "ester" are alone inappreciably affected.

(iii) The fatty acid and the phosphate complexes of fresh latex undergo extensive hydrolysis within eight weeks of ammoniation, and part of the inorganic matter is firmly retained by the modified hydrocarbon. (See (v) below.)

(iv) The crude caoutchol of fresh latex is replaced by an increased amount of a viscous fluid which is thought to consist of a disaggregated portion of the hydrocarbon. Caoutchol itself, treated with dilute aqueous ammonia, becomes relatively insoluble, and is presumably retained on analysis by the remainder of the hydrocarbon.

(v) The hydrocarbon of fresh latex is replaced by an ash-containing material which has a marked resistance to solvent action. This latter property is due not only to retention of the modified caoutchol (iv above), but also to modification (? polymerisation) of the hydrocarbon itself by the action of the ammonia.

Acknowledgments

I wish to express my thanks to Mr. S. A. Nathan and Mr. K. H. Rajagopal for their assistance with the analytical work involved in this and the two preceding papers, and my indebtedness to Dr. E. Rhodes for much helpful discussion and advice.

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Kuala Lumpur,

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THE USES OF STATISTICS IN FIELD EXPERIMENTS WITH RUBBER TREES*

BY

H. J. Page

There is an old gibe that there are three grades of falsehood: —"Lies, Damned Lies and Statistics." The intention here is to show that statistics, properly used, so far from being the acme of falsehood, is indeed common-sense in a highly developed degree. Huxley defined Science as "organised common-sense," and this is a definition which is specially appropriate here, for the application of statistics to field experiments has made it possible to carry these out in a scientific manner not before possible, and to interpret their results with a high degree of scientific precision. Statistics have in fact brought a large amount of common-sense to bear on the conduct and interpretation of field experiments.

It must of course be understood that the term statistics is used here not in the loose sense of the mere collection and classification of numerical data, but in the specialised sense of the use of higher mathematics for the analysis and interpretation of data, and for the design of experiments. It is not intended to attempt to explain the mathematical principles involved or the manner of their use. That is the job of the higher mathematician himself—so much so that although other scientists have to understand the general principles of the application of statistics to the design and interpretation of experiments, it is nowadays best left to the specialized mathematical statistician to undertake the actual work of applying his methods. It is for that reason that the Rubber Research Institute has just appointed a Statistician to its staff.

What is an Experiment?

An experiment is defined in Webster as "A trial . . . . . made to confirm or disprove something doubtful"—and in the case of rubber-growing, the "something doubtful" is whether a certain method of treatment or a certain type of material is better than others, and therefore worth while to adopt.

Anyone can carry out an experiment, and can obtain results therefrom. But that is less than half the battle. The experiment

* The substance of a lecture at the Annual Conference of the Incorporated Society of Planters at Kuala Lumpur on 17th September, 1937.

may have been so badly designed or so badly conducted that it cannot possibly give results capable of valid interpretation; or it may have been well designed and executed, and yet the meaning of the results may be obscure or misunderstood.

Let us take as our first example an experiment intended to compare only two things,—or "treatments" as they are usually termed,—for instance to compare the yielding power of one clone with that of another, or with that of seedlings, or to ascertain the relative merits of two tapping systems, or the effect of a given fertiliser on the yield of rubber trees. What would appear at first sight to be the obvious way of doing this would be to take two adjacent plots of land as alike as possible, and to apply the two treatments one to each, and then to compare the results obtained.

Now the crux of the whole matter is that more often than not this is an entirely misleading and unreliable way of doing a field experiment, and the chief object of this paper is to explain why this is so.

"Single-Plot" Experiments

The practical man is strengthened in his unwillingness to accept this verdict by the fact that the earliest and best known agricultural field experiments were carried out in this way, as "single-plot" experiments; that is, with only one plot for each treatment. Many of the most important advances in scientific agricultural practice are based on the results of such "single-plot" experiments. The world-famous manuring experiment on Broadbalk Field at Rothamsted for instance, from the results of which our knowledge of the main principles of manuring was first derived, is a "single-plot" experiment, started in 1843 and is still going on.

The reason for this is that if the effects which the experiment is intended to study are big enough, "single-plot" experiments will establish them with sufficient certainty. The Broadbalk experiments just referred to showed increases in yield of the order of 50 or 100% or more—in fact at the present time the plot receiving no manure gives barely 10 bushels, whilst the plot getting a liberal "complete" manuring gives over 30 bushels: an increase of about 200% over the control! If we knew beforehand that the effects to be studied in our field experiments were always as big as that, we could probably do well enough with "single-plot" experiments, if indeed we should then bother to do any experiments at all! But unfortunately the effects we wish to measure nowadays are more often only a matter of differences of 10 or 20%

instead of 100 or 200%. They may be no less important for all that. A 20% increase in yield of rubber, yielding before treatment 400 lb. per acre, *i.e.* an increase of 80 lb. per acre, may represent a handsome, profit, perhaps 100% on the cost of getting it. But an increase of 20% usually cannot be detected with certainty from a "single-plot" experiment.

Two adjacent tasks, one of which is manured and the other not, may give yields of 400 and 480 lb. rubber respectively, and yet the difference may have nothing whatever to do with the manuring. Even if previous records for the two tasks indicated that they then both gave 400 lb., the difference of 80 lb. after manuring may have been due to other factors entirely unconnected with the manuring. Moreover, unless special steps have been taken to ensure that the previous records do actually represent the true yields of the two tasks, there is no guarantee that they do; for tappers are notoriously prone to level up their deliveries of latex from adjoining tasks. All the same, as explained later, the existence of previous records does help to improve the reliability and to simplify the layout of experiments on mature rubber. But for "single-plot" experiments for which suitable past yield-records are not available, such as comparisons of different planting material; or cultivation and manuring experiments on young rubber; one is entirely at the mercy of the variations in the fertility of the soil over the area chosen for the experiment, as well as many other varying factors outside one's control.

Plot Variability. "Uniformity" Trials

Before going any further to explain this, a few examples follow:—

Nos. I—V show the yields from the untreated control plots from various experiments.

Nos. VI—VIII show the yields from adjoining plots, or "uniformity trials."

I

	973
926	
	807
944	

Difference between adjacent plots in centre=14%.

II

		511
680		
	531	

Difference between adjacent plots=25%

III

		202
211		
	206	

Exceptional uniformity.

IV

119		120					162

Right hand plot 35% in excess of other two.

V

179	179			155	153			106	121

Good agreement of adjacent plots in two cases, but 14% difference in the third case, and a pronounced "drift" from high yields on left to low yields on right.

VI

102	93	90	92	97	98	91	89	99	100

A "uniformity trial" showing fair agreement, but a range of 13% between highest and lowest yields.

VII

A	B	C	D	E	F	G	H
3.5	3.5	4.3	3.5	3.3	3.3	3.9	4.3

Yields from adjacent tasks (in gms per 100 trees per tapping).
Differences between adjoining tasks, and the same as percentages, are shown below.

Nil	0.8	0.8	0.2	Nil	0.6	0.4
—	20	20	5	—	15	10 %

VIII

A uniformity trial of 78 plots. The yields showed a total range of variation of nearly 60%, and examples of yields from adjacent plots are as follows:—

73 133	Difference =	58% of mean
103 84	„ „	18% „
112	„ „	28% „
89 117	„ „	27% „
106 79	„ „	29% „
115 83	„ „	32% „

These are all actual instances of the yields obtained from adjoining or closely situated tasks of rubber, to which no different experimental treatments have been applied, *i.e.* which have been treated, as nearly as practicable, exactly alike. Admittedly some of these are chosen deliberately as horrid examples, but they are none the less actual instances of the variation that may occur. Others of the examples displayed show that sometimes there may be a high degree of uniformity. The point is that one never knows with even reasonable certainty what the extent of this natural variation is. All the areas in question were chosen to represent the most uniform land and rubber available on the estate. This is an effectual answer to the planter who insists on using only single plots; and who says: "The other chap may have to use an elaborate modern experiment to get results, but I know my soil and my rubber so well that I can rely on the results of single plots." That is as often as not just sheer nonsense. Agricultural scientists have found by bitter experience that even on the most level and uniform-looking land, with apparently uniform planting material, be it an annual crop or perennial, differences in yield of the order of those shown on the diagrams are only too commonly found. Originally agricultural scientists were just as unwilling and reluctant as the farmer or planter, to adopt the modern type of elaborate layout of field experiments. The remark of a certain distinguished professor of agriculture:— "Damn your duplicate plot; give me single plots and I know where I am," is typical of the attitude which has had to be given up after hard experience. He thought he knew where he was, but more often than not he would have been quite wrong.

The reason for this uncertainty is that with all natural material, living or inanimate, there is a greater or less degree of

variability, which is not the case with pure substances. The chemist working with pure substances is largely free from this trouble. He does not have to do an experiment, for instance, to find out whether sulphuric acid and caustic soda will react together and neutralise one another. He knows that they always will; that 98 grams of H_2SO_4 will always be exactly neutralised by 80 grams of NaOH to give 142 grams of Na_2SO_4; and that a fixed and constant amount of heat will be liberated. All molecules of sulphuric acid or of caustic soda are chemically alike. But no two individuals of any living kind are exactly the same, nor are any two samples of natural material, and the behaviour of an individual or a sample cannot be predicted with certainty. It is this innate variability of natural material, and of the environmental conditions, which places experimentation with such materials, and particularly with living materials, on an entirely different plane from experimentation with pure substances. The statistician's job is to study variability and its effects, and it is for that reason that the assistance of statistics is so necessary in the design and interpretation of field experiments.

Factors responsible for Variation

Let us examine the factors responsible for variation in field experiments with rubber trees. In the first place there is the variation in "fertility" between different plots of land. In a properly-designed experiment this is the biggest source of variation. Even the most uniform-looking area of land may possess quite big variations from one place to another. Even if the surface soil is quite flat and apparently uniform, there may be invisible differences in the nature and depth of the subsoil. The sporadic occurrence of a hard pan, at varying depths, is a special case of this, and instances often occur in which the existence of such a hard pan is first discovered only as a result of poor sickly growth of trees in patches. Moreover, an apparently uniform top soil, of uniform depth, may yet hide differences in fertility through differences in the previous cropping history of the area; a part may have been heavily depleted of available plant food by previous cropping with, say, tapioca. On many estates it is practically impossible to find any level areas of land, and experimental areas have to be on hillsides, with considerable differences in the soil, and in conditions such as drainage, between the higher and the lower land.

Added to these inherent variations in the soil, are variations in the rubber trees. By choosing plots of the size of a task, with over 200 trees, the effect of the large tree-to-tree variability, which occurs especially with seedling rubber, is largely eliminated;

and differences in age or origin of trees should always be avoided by choosing an area which was all planted at the same time with uniform material (except of course in an experiment for the comparison of different sorts of planting material). There still remain the effects of uneven attack by pests and diseases, of differences in tapping history or in average height of tapping, whilst there is also the possibility of lack of uniformity in the conduct of the experiment and in the collection of the results.

Size of Uncontrollable Variation

The uncontrollable variation due to differences in soil and subsoil,—or "soil heterogeneity" as it is usually called,—will sometimes be slight and sometimes be large, whilst the other factors instanced above will similarly differ in their incidence from place to place and time to time. Thus the sum total of the effects of all these factors, as reflected in the growth or yield data obtained from the plots, will also vary between wide limits, as shown by the examples above, where in some cases the yields show a very satisfactory approach to uniformity, as between different plots, whilst in other cases the differences may be over 25%. The important point is that one can never be sure beforehand what the position is.

Suppose that the two plots A and B of example VII above had been chosen to compare two clones, and that a difference of 20% had shown up between them in growth, or in yield when they came to tapping, then one would in fact be reasonably safe in drawing the conclusion that the two clones did actually differ, on that soil, by about 20% in their growth or yield. On the other hand, suppose that plots C and D had been chosen, without the knowledge which the "uniformity" test has here revealed. The two clones might be identical in their inherent yielding capacity, and yet the natural "soil heterogeneity" between the two plots would result in a difference of 20%, which would be quite erroneously interpreted as a difference in the clones themselves, if the results of only that one single-plot experiment were accepted as valid.

This is sufficient to demonstrate how unsafe it is to rely on the results of "single-plot" experiments—save under certain special circumstances mentioned later.

Regular and Irregular Variation

Uniformity trials such as those which are represented above, are trials in which the area in question is divided up into plots which are harvested separately, without any difference in treatment. These enable *fertility contour diagrams* to be drawn. These

are similar to the height contours so familiar on ordinary maps. There are peaks of high fertility, hollows and valleys of low fertility, and intermediate slopes of average fertility. Now if changes of fertility of this sort occur *within* one experimental area, it is clear that the variation from plot to plot is irregular, though contiguous plots are likely to be less different than those more widely separated.

On the other hand the scale of the fertility contour map may be smaller, so that the whole of an experimental area falls on a patch of regularly varying fertility. The pitfalls into which a regular fertility gradient or "drift" of this kind can lead, are well illustrated by a case recorded some years ago, which is illustrated below.

0	10	20	30	40	50		Cwt. of lime per acre.
A	B	C	D	E	F	X	
20	22	24	26	28	30		Yield.

There were seven plots in a row, the first receiving no treatment, and five others receiving, in order, 10, 20, 30, 40 and 50 cwt. of lime per acre. The yields obtained may be represented by the figures underneath the plots, *e.g.* a steady increase in yield from 20 to 22, 24, 26, 28 and 30 units—apparently a clear case of increasing benefit to the yield from increasing amounts of lime. Fortunately, (or unfortunately!) a second control plot was included at the other end, marked X on the diagram. The yield from that control plot was 32! The lime had really no effect on yield at all; all that the experiment showed was a uniform fertility drift increasing from left to right. But for the afterthought of adding a duplicate control plot at the other end, this would not have been discovered, and it would have been concluded that lime had an increasingly beneficial effect on that soil, in dressings at least up to 50 cwt. per acre!

It might have happened, however, that the experiment was laid out on land with a peak of high fertility in the middle, in which case the two control plots one at each end would have given similar yields, and it would have been concluded that the land was of uniform fertility, unless another control plot had been included in the middle to reveal a yield much higher than those from the plots at the two ends.

One of the earliest methods of guarding against misleading results of this kind was to make every other plot a control plot, as below.

A	B	A	C	A	D	A	E	A	F	A

A = Control Plots.

B, C, D, etc. = Treated Plots.

Then by comparing the yield of each treated plot with the average of the yields of the two control plots one on each side, a more accurate measure of the treatment was obtained. But what a wasteful and cumbrous method of experimenting! Half the total number of plots is given up untreated to controls, and there is still only one single plot for each treatment. All the same, this was a definite move in the right direction, for it introduced the principle of repetition, or "replication" as it is now called, (as a useful word to cover duplication, triplication, and so on, up to any desired degree of repetition).

Replication

In view of the chances of variation between plots, it is obvious that if there are *several* of each treatment, distributed over the whole area, the *average* result obtained from all the replicate plots of any one treatment is much more likely to represent the real yield obtainable with that treatment under the average conditions of that area, and comparison between such averages for different treatments is far more likely to be a true indication of the relative effects of those treatments.

Replication is the first essential of a reliable field experiment, and in all modern experiments each treatment (including the control, if any) is replicated the same number of times. Let us take four-fold replication, (that is, quadruplication), as an example. In the following diagram is an experiment with four treatments, A, B, C and D, with four plots for each treatment.

A	B	C	D
D	A	B	C
C	D	A	B
B	C	D	A

This is typical of the kind of experiment first adopted after the need for replication came to be recognised. It includes adequate replication, but its arrangement is *systematic*. A, B, C and D always follow one another in the same order.

Experimental Error

Now we have seen that owing to "soil heterogeneity" and other uncontrollable factors, the results obtained from an experiment are lacking in accuracy to a greater or less degree. The extent to which the results are therefore not completely accurate is the "experimental error," termed mathematically the "standard error" or the "probable error" according to the mathematical convention used to calculate it. It is expressed as $\pm$ X, where X is a number; the higher X is, the more inaccurate the experiment is and the less reliable are the results. A probable error of say $\pm$ 10% applying to an average yield of say 100 units from a given treatment, means that owing to the influence of uncontrolled variation in the conditions of the experiment, that average is inaccurate, and that there is a good chance that the true value might be only 90 on the one hand, or 110 on the other, or anywhere between; it is impossible to say, between those limits just what it really should be.

The object of a properly-designed field experiment, so far as the experimental error is concerned, is not only to make that error as low as possible, but also, *equally important*, to make it possible to calculate that error accurately. The use to which the results of an experiment are put is to decide how the effects of different treatments compare. This involves studying the *differences* between the average results for the two treatments under comparison. Supposing one treatment gives an average of 100 and another an average of 120. If the "probable error" of each is $\pm$ 10%, that means that the treatment with the average of 100 may be taken as being possibly anything from 90—110, and the other as anything from 108—132. The difference between the averages for the treatments may therefore be anything from -2 to $+42$! The apparent superiority of 20% of the second treatment over the first has changed into the complete uncertainty, whether perhaps it is no better, or whether perhaps it is very much better. This is taking rather an extreme and crude example —the mathematician has more elegant and exact methods of treatment—but it serves to illustrate my point. Supposing the probable error has been wrongly estimated and that it is really only about 5% instead of 10%, what a difference that would make to the value of the results.

The fault of the systematic arrangement of plots, with replication, is that whilst it reduces the experimental error, it does not allow the true value of that error to be calculated, and as just explained, it is not much use improving the accuracy of results if you do not know what that accuracy is.

Randomisation

The other requirement of a properly laid out experiment, in addition to replication, is "*randomisation.*" That simply means that the arrangement of the plots is not systematic, but at random, —according to chance. If the previous diagram is compared with the following one

A	D	B	C
D	C	A	B
C	B	D	A
B	A	C	D

it is seen that whilst in the first one, A, B, C and D always come in the same order in each row or column, in this one that is not so,—they are arranged at random in each. The order in which the treatments are assigned, in a randomised arrangement, is one of the many in which they might come if dealt from a shuffled pack of cards, or thrown with dice, or drawn from a hat.

It is a requirement of the mathematical statistics whereby the standard error is worked out, that if the estimate of that error is to be *valid*, the arrangement of treatments in each experiment, or section thereof, must be at random, not systematic. We have seen already that it is not any use calculating the experimental error unless it is really an indication of the true error, and here it must be taken on trust that randomisation is essential for that purpose. The mathematical arguments underlying that fact are perfectly sound but far too involved to explain now.

Randomised Blocks and Latin Squares

The commonest and best-known arrangements in which the great majority of properly-laid-out field experiments are included, are *Randomised Blocks* and *Latin Squares.* Many will be familiar with these from the schemes of experiments they are doing in co-operation with the Rubber Research Institute, the Department of Agriculture or with other concerns. It is hoped that after the attempt to explain why they are necessary, and the further attempt later on to explain how they work, planters will be happier in their minds about what must often have seemed the rather unreasonable requirements and conditions they are asked to conform to in such experiments.

In the case of the *Randomised Block* experiments illustrated below

Two Examples of Randomised Block Experiments

(Plot yields shown only for Control (A) Plots)

		Block Totals
Block 1	A 17.5 | C | D | B | E	102
„ 2	E | C | B | D | A 27.2	122
„ 3	E | B | D | A 18.7 | C	127
„ 4	A 21.8 | B | D | C | E	128
„ 5	D | C | E | A 23.6 | B	134

Standard Error of Difference between Treatment Averages=8.8%.
Significant Difference between Treatment Averages=17.6%.

An example of a Randomised Block experiment showing rather a high experimental error, as was to be expected from the big variation in yields from Control (A) plots.

		Block Totals
Block 1	D | C | E | A 3.2 | B	16.6
„ 2	E | C | D | B | A 3.2	16.9
„ 3	C | A 3.2 | D | B | E	17.3
„ 4	A 3.1 | D | B | C | E	16.7
„ 5	E | B | D | C | A 3.1	16.9

Standard Error of Difference between Treatment Averages=2.6%.
Significant Difference between Treatments Averages=5.2%.

An example of a Randomised Block experiment with a low experimental error, as was to be expected from the uniformity in yields from the Control (A) plots, and in the Block totals.

we have five treatments, A, B, C, D, E, and five-fold replication, so that there are five separate blocks. In each block there are five plots, one for each treatment, and the allocation of these treatments is entirely at random, that is, in the order in which they might be drawn from a hat. The random arrangement is different in each block, representing a fresh drawing from the hat for each.

An Example of a Latin Square Experiment

R.R.I. Experiment Station Block 6, 1936

Letters = Treatments

Numbers = Plot Yields

						Row Totals
B 391	A 330	C 374	D 362	F 339	E 372	2168
C 414	D 399	F 384	E 387	B 392	A 375	2351
F 395	C 445	E 336	A 391	D 362	B 329	2258
D 393	B 394	A 383	C 440	E 361	F 386	2357
A 378	E 373	B 391	F 399	C 390	D 373	2304
E 337	F 372	D 350	B 397	A 352	C 454	2262
Column Totals	2308	2313	2218	2376	2196	2289	2283

Treatment Averages	A	- 368	97%
„ „	B	- 382	100%
„ „	C	- 420	110%
„ „	D	- 373	98%
„ „	E	- 361	95%
„ „	F	- 379	100%
Standard Error of Difference between Treatment Averages		... ...	3.44%
Significant Difference		... ...	7. 0%

The *Latin Square* is a slightly more restricted arrangement, in which the number of replications is the same as the number of treatments. We have such a 6 × 6 Latin Square illustrated above.

It is not necessarily a geometrical square, for the individual plots may be longer than they are broad, but it is called a square because it has the same number of plots, 6, in each direction. It may be regarded as six randomised blocks, either vertically or horizontally, and it is so in fact, in so far that the arrangement of the treatments in each row or each column is at random, but with this important restriction, that any one treatment must not occur more than once in any one row or in any one column.

An essential feature of experiments of this type is that the *total* yield for a block (in a Randomised Block experiment) or from a row or column (in a Latin Square experiment) is contributed to by each treatment alike. In the above Latin Square, one-sixth of the area of each row or column is untreated control (A), one-sixth has received treatment B, one-sixth treatment C, and so on; so that all treatments have an equal share in their effect on the block, row or column total. The comparison of these totals thus does not involve main differential treatment effects, and is an indication of the variation due to other uncontrolled factors. Variations in "soil heterogeneity" can be observed from variations in block, row or column total, and by a mathematical treatment of those totals, a large part of the error caused by "soil heterogeneity" and the like can be calculated and can be eliminated from the error attaching to the comparison of the treatment totals, so increasing the accuracy of the experiment.

"Significant Difference"

An attempt will now be made to explain what is meant by another term which is used very frequently in stating and interpreting the results of an experiment, the term "Significant Difference." To do this, it must first be remembered that the irregularities due to "soil heterogeneity" and other causes are distributed more or less at random over the experimental area, and that it is a matter of *chance* whether any particular plot will be on an area which is above or below, and much or little above or below, the average. The mathematical treatment of the results must therefore be one which deals with the assessment of *chances* or *odds*, or as the mathematician calls it, *probability*.

When a "standard error" is said to be ± 10% that does not mean that the result could not possibly be even less accurate than that, but that the odds are in favour of the inaccuracy not exceeding ± 10%. Since there are so many variable factors not

under complete control in any experiment:—soil, weather, disease, Tamil coolies etc., and since the incidence of these factors can never be exactly known, there *must* always be *some* uncertainty regarding the accuracy of the results obtained, however well the experiment has been designed and carried out. The object of the application of statistics to the design and to the interpretation of field experiments is to reduce that uncertainty as far as possible, and to define it. This is done by stating the experimental error and the "significant difference" in terms of probability or odds. It is open to anybody to decide what degree of probability he is willing to accept as good enough for him in practice, and circumstances may often dictate whether long odds or short odds are worth while.

The odds that are usually accepted by the scientist in the interpretation of field experiments are *20 to 1*, or *95% probability*. (P=0.05.) As explained already, there is always a chance that the difference between the average results for two treatments, even from the best-designed and executed experiment, is caused by chance, *i.e.* by the operation of the uncontrolled variables included in "soil heterogeneity" etc., and not by the difference in the treatments applied. If the mathematical analysis of the data shows that the odds are 20 or more to 1 that this is not so, *i.e.*, that there is at least 95% probability that the difference *is* caused by the difference in the treatments, then that difference is said to be "significant," and the "significant difference" is the minimum difference allowing these minimum odds.

Any difference between treatment averages which is less than this "significant difference" is "insignificant," *i.e.* it is not safe enough to ascribe it to the difference in treatments, because the odds against its being caused merely by chance are less than 20:1. Anybody who is prepared to take more of a chance, is perfectly at liberty to do so. He may wish to accept 10:1 odds instead of 20 to 1, in which case a smaller difference is accepted as caused by the treatments under test.

As in other walks of life, the amount of chance one is prepared to take depends on what is at stake. To take action on a low probability may be worth the risk when the result of the gamble is big enough if it succeeds, but anybody doing so must admit that it *is* a gamble, involving risks bigger than the scientist is justified in giving his blessing to—even though *he* also may sometimes be forced to take them. When therefore a difference is stated by the scientist to be "significant," remember that it does not mean that it *must* be a real and not a chance difference, but only that the risk of its being a chance difference is so small as to be fairly safely accepted. Similarly when the

result is said to be "not significant," it does not mean that it cannot possibly be real, but only that the risk of its being only a chance difference is too big for safety.

When Single-Plot Experiments may have some value

It was mentioned earlier in this paper that if the difference is big enough, even "single-plot" experiments can be relied upon. Thus if the yield of one plot is double that of the control, the odds are pretty high that this is chiefly the effect of the treatment, but if the difference is only 10 or 20%, the odds are perhaps 5 or 10 to 1 *against* its being due to anything except chance.

There are two other factors which may greatly reduce the uncertainty of the results from single plots. The first of these is the *time factor*. If single plots have been carried on for a number of years, with careful recording of yields all the time, it may be possible by studying the relative behaviour of the plots during that time, to find differences in trend; the yield of one plot may have gone steadily up and that of another steadily down. Statistical analysis of such results is possible, and may often yield results of fair reliability. There is in fact replication here, though it is replication in time, not in space. But we do not want to wait for years to get definite results, if we can possibly avoid it, so whilst this is some consolation to those who have records of single-plot experiments started some years ago, it is no recommendation, and is not intended to be, that single-plot experiments should be laid down now.

The other factor is the *personal factor*. The planter who knows his rubber well can often see effects which have not or cannot be accurately recorded. It may not need more than a single plot to enable, *e.g.* the effect of manures on foliage and canopy to be clearly seen. If an area in which the trees had small sickly-coloured leaves, thin canopy and obvious "stag heads" and die-back, develops in a thick dark green canopy of large well-formed leaves, with lots of new growth in a few months after manuring, so that its improved condition leaps to the eye in comparison with the area not manured, then it would be sheer nonsense to deny, because only a single plot had been used, that the improvement was practically certainly caused by the manuring. Less spectacular differences in bark condition may also be detected with reasonable certainty by the man who knows his trees well. Should such improvements later be paralleled by the recording of a higher yield from the manured plot, then it is more likely that this is an effect of the manuring, even if it cannot be taken as sufficiently probable to satisfy the statistician.

We must remember that the statistician is the servant, not the master, of the experimenter, in much the same way that the architect is the servant, not the master, of the owner of a building. We expect the architect to design for us a building which is safe, and suitable for the use to which it is intended to be put, and so long as the building is properly constructed to that design, he takes the responsibility for its safety and suitability; but if we ask for a design for a dwelling house and he submits one more suitable for a block of offices, we do not have to accept it; whilst if he submits alternative designs, it is for us and not for him to decide which shall be accepted. We are perfectly at liberty to erect a building without any design or advice from an architect (that is, assuming we are outside the jurisdiction of the Municipal Authorities!) provided we do so on our own responsibility and do not ask him to accept any.

In just the same way, the experimenter is obviously quite at liberty to carry out "single-plot" experiments, and to draw his own conclusions from them, perhaps merely because he has a "hunch" that the result is so and so, or because he knows from his own observation that there have been effects which could not be recorded in figures, so long as he does not expect the statistician to take any responsibility for them, and so long as he does not expect others blindly to accept his conclusions. The rigorous mathematical tests which the statistician applies, on the other hand, serve as a guarantee which others can readily accept, and so they enable experimental results to be of use to the whole body of planters. But such tests can be validly applied *only* if the experiment is properly laid out in the manner already exemplified.

Variation between Localities. Field Experiments and Soil Surveys

It goes without saying that the results of an experiment in one locality cannot be unreservedly applied to another where conditions of soil, climate, trees etc. are different. Due allowance must always be made, if it can, for such differences and it is here that the close relation between soil survey and field experiments is of such importance. The two should always go hand in hand, for when the soils of a country have been properly mapped as the result of a soil survey, it is possible to decide how far results obtained from experiments on a given type of soil are applicable in other places, according as the soils in those other places resemble or differ from that of the locality where the experiment was carried out.

Until such knowledge of soils is available as a result of a soil survey, advice on rubber cultivation in localities where the soil has not been examined and experimented on must always be of less sureness. The scheme of experimental planting under the aegis of the Rubber Research Institute, along with the soil survey work which is being done, is for that reason of the utmost importance, and may be expected to yield results of the greatest value to the rubber-growing industry of Malaya in due course.

Logical Selection of Problems

There is another aspect of field experiments with rubber: that of the choice of treatments in the scheme of the experiment. This refers more particularly to manuring experiments. There is sometimes a tendency to jump ahead to the study of matters of secondary importance before those of over-ruling primary importance have been elucidated. Thus experiments have sometimes been laid down to test, for instance, which form of phosphatic manure is best—say rock-phosphate or super-phosphate—or what is the most effective amount to use,—before it has been found out whether on the soil in question there is need for any phosphate at all. The first essential question is, does the use of nitrogen, or of phosphate, or of potash, produce any result. Only if any one or more of these is beneficial, is it worth while comparing the relative merits of different forms of nitrogenous, or phosphatic or potassic manures as the case may be, or the relative effects of small and larger dressings and so on.

At the same time, in view of the relatively long time which must elapse in experiments with rubber trees before results of reasonable certainty are obtained, it is only natural that one should wish to avoid having to tackle the problems only in this logical order one after the other. An important recent advance in the design of experiments is one which enables many of these different questions to be answered together by an experimental layout which is not much more complicated than that which is needed to answer only one set of problems at a time. Such an experiment has the further advantage that it may supply important information on what is known as the "interaction" of factors.

No attempt will be made here to explain in detail what is meant by this "interaction," but the kind of thing it covers is well enough illustrated by the following example. A soil might be so very deficient in phosphate that plants could not make more than very poor growth on that account, and so long as no phosphatic manure was given, nitrogen manures had little or no effect. The use of phosphatic manures would have a marked

effect, but the much improved growth or yield thus resulting might *then* be prevented from being still better because the soil was not too well supplied naturally with nitrogen. The use of a nitrogenous manure along with phosphate would then produce a pronounced effect, additional to that produced by phosphate alone. That would be called a nitrogen-phosphate interaction, for the effectiveness of the nitrogen was subject to the presence or absence of phosphate. Nitrogen and phosphate together then give a bigger effect than the sum of the effects either gives in the absence of the other.

Practical Aspects of Field Experiments with Rubber Trees

It is not possible to deal here with certain special aspects on the practical side of the conduct of experiments on rubber, such as the size and shape of plots, the effect of individual variations between tappers, the effect of the average tapping height, avoidance of interference or "poaching" between adjacent plots, and so on. There is however one important aspect to mention. Hitherto it has been customary to use plots consisting of whole tasks or at most half-tasks, owing to the difficulty of organizing the tapping of smaller units without great uncertainty as to the reliability of the results. However, even when the results are obtained in the form of the yield of dry rubber from normal-sized tasks, it is often impossible on estates to supervise the collection and carrying-in of the latex by the coolies well enough to be reasonably sure that there has been no levelling-up of the amount of latex from different tasks. Such levelling-up will, of course, tend to vitiate the results of the whole experiment.

Another service which statisticians have done to field experimentation is the study and development of sampling methods for determining the yield of plots, instead of weighing the whole produce from them. Such methods should be particularly applicable to, and valuable for, experiments with rubber trees, when the annual yield of a given task is made up of perhaps 250 individual tree-tappings on each of say 150 days, or 37,500 separate samples. Work is now being done at the Institute on this subject, and also by Dr. Haines of Dunlop Plantations Ltd.

It may be expected that by collecting the latex separately from only perhaps one tree in every ten, on perhaps only one or two days a month, or less, considerably more accurate results from experiments will be obtained. Moreover, such a method would have the further advantage that individual plots in an experiment need no longer be as big as tasks or even half tasks. Subject to their not being so small as to introduce extra troubles

from individual tree-variation, they can be any size desired. For budded rubber in particular, where the uniformity from tree to tree is much higher than with seedlings, very considerable reduction in the size of plots may be possible.

Conclusion

In spite of some digression from the original theme of the reason why the modern type of layout of field experiment is necessary, and how the statistician's services can be of enormous value to field experimentation with rubber, it is hoped that it has been convincingly demonstrated that the old idea of "single-plot" experiments, which still dies hard with many planters, is really of very little use. As to *how* the modern type of experiment—Randomised Blocks, Latin Square and the more complex type I mentioned a short time ago—do what they have been stated to do, this is a matter which can be properly explained only in terms of rather abstruse mathematics, and in this place it must suffice to refer to the notes and explanation appended to the examples above.

In conclusion, it is apt to cite the words of Robert Boyle, written in 1673, under the title of "Concerning the Unsuccessfulness of Experiments" as quoted by R. A. Fisher at the commencement of his book on "The Design of Field Experiments":—

> "I am very sorry, Pyrophilus, that to the many (elsewhere enumerated) difficulties which you may meet with, and must therefore surmount, in the serious and effectual prosecution of experimental philosophy I must add one discouragement more, which will perhaps as much surprise as dishearten you; and it is, that besides that you will find (as we elsewhere mention) many of the experiments published by authors, or related to you by the persons you converse with, false and unsuccessful (besides this, I say), you will meet with several observations and experiments which, though communicated for true by candid authors or undistrusted eye-witnesses, or perhaps recommended by your own experience may, upon further trial, disappoint your expectation, either not at all succeeding constantly or at least varying much from what you expected."

Kuala Lumpur
17th September, 1937

BOOK REVIEW

Polymerization and Its Applications in the Fields of Rubber, Synthetic Resins, and Petroleum BY R. E. BURK, H. E. THOMPSON, A. J. WEITH AND IRA WILLIAMS (*Reinhold Publishing Corporation, New York*).

The latest addition to the series of American Chemical Society Monographs is a masterpiece of compression. The text of less than 300 pages involves more than 1,300 informative references to original work. The aim of the authors has been to give a complete resumé of both the theoretical and the practical aspects of their subject, and in this there is no doubt that they have been remarkably successful. The book will accordingly be an indispensable work of reference to the scientific staffs of the rubber, synthetic resin and petroleum industries. But it is far more than a comprehensive catalogue. Both facts and theories are subjected to critical scrutiny, and the book will therefore commend itself also to those having a more general interest in the subject of polymerisation.

Despite the vast field covered in a small compass, the authors have found room for the adequate expression of their views, and it is both unexpected and pleasant in a book of this type to read the following: "We are now coming to realise that more effort spent in studying the chemical nature of the different products... .....would have paid, perhaps, a richer reward than much of the work which has gone directly into forming a commercial article on the basis of the little fundamental information available. This is true because the physical characteristics of a material which determine its value as an article of commerce are ultimately dependent on the chemical structure of its components" (p. 211). This is said with reference to synthetic resins, but the context makes it clear that the authors believe the sentiment to be true in general.

The authors, while using the term polymerization in a wide-enough sense to include the synthetic resins, are careful to exclude association phenomena. They also justly point out that the formation of natural rubber by polymerisation of isoprene or other terpenic hydrocarbons is improbable. The science of natural rubber has therefore little relationship to the subject of the monograph, and the bulk of the chapter "Polymerisation in the Rubber Industry" is accordingly devoted to synthetic rubber, with a brief treatment of vulcanisation in which polymerisation possibly plays a part.

The Table which covers 58 of the 61 pages of Chapter III is a remarkable compilation which calls for special comment. This encyclopaedic presentation of data concerning polymerisation catalysts is eminently usable.

Factual and textual errors throughout the book appear to be very few, but it should be pointed out that formic acid is now used more generally than acetic acid as a latex coagulant (p. 162). Two formulae have been omitted seven lines from the bottom of p. 203. A type-setting error has produced a break in the text at the foot of p. 202, but by a very happy coincidence one resumes reading at the top of p. 203 with the words "proceed again apparently as if no interruption had taken place"!

Finally, may one make so bold as to commend to American colleagues the use of "many-membered" instead of "large-membered" and of the legitimate, brief word "placing" instead of "positioning"?

K. C. R.

Kuala Lumpur,

13th November, 1937

BOOK REVIEW

The Chemistry and Technology of Rubber—American Chemical Society Monograph Series No. 74.—Edited by C. C. Davis and J. T. Blake (*Reinhold Publishing Corporation, New York, 941 pages*).

The subject matter of this book is contained in twenty-six chapters on different aspects of the chemistry and technology of rubber, each chapter being the work of an acknowledged expert or experts in the particular field under reference. The contributors are mainly American and are drawn from all the important rubber and cable concerns and government departments in that country. The remaining authors are well-known British, French and Dutch chemists. It goes without saying therefore that the work is authoritative.

Three chapters are given to the composition, the physical properties and the chemical structure of raw rubber. The first of these is by A. van Rossem, the second by G. Stafford Whitby and the third by H. L. Fisher and R. H. Gerke. These three chapters together cover 141 pages. The subject of mastication and plasticity is covered in a 31-page chapter by W. Gallay. The 56-page chapter on structure and behaviour of rubber in solvents by W. F. Busse leads up to the subject of vulcanization of which the various aspects are given five chapters occupying a further 143 pages. These five chapters deal with the theories and phenomena of vulcanization, vulcanization without sulphur, the history and use of accelerators, theories of acceleration and the physics of vulcanized rubber, and are contributed by Ira Williams, H. Ostromislensky, S. M. Cadwell with J. W. Temple, W. Scott with L. B. Sebrell, and W. W. Vogt respectively. A chapter than follows on fillers and reinforcing agents by N. A. Shepard, with J. N. Street and C. R. Part, occupying 34 pages. This is followed by three chapters totalling 143 pages on deterioration of rubber. Here the history and use of materials which improve ageing are dealt with by W. L. Semon, auto-oxidation and deterioration by oxygen by C. Dufraisse and deterioration by heat, light and ozone by F. H. Cotton. Then comes a contribution by A. T. McPherson on the electrical behaviour of rubber to which 38 pages are devoted. Two chapters on latex follow; the first of 15 pages on properties, by W. A. Gibbons and P. D. Brass, and the second of 25 pages on industrial uses of latex by D. F. Twiss, E. A. Murphy, E. W. Madge, and G. W. Trobridge. The subject of hard rubber (ebonite) is next discussed in 21 pages by A. R. Kemp & F. S. Malm, and is followed by a 21-page chapter on rubber derivatives of commercial

utility by T. R. Dawson & P. Schidrowitz. Thomas Midgley Jr. describes synthetic and substitute rubbers in 28 pages and J. N. Dean devotes 15 pages to gutta-percha and balata. Reclaimed rubber receives a 19-page description by G. W. Miller and practical compounding occupies 38 pages by W. F. Russell. Two chapters on physical testing and chemical analysis by A. W. Carpenter on the one hand and R. P. Dinsmore with R. H. Seeds and H. E. Rutledge on the other, occupy 106 pages, and C. C. Davis's admirable contribution on the literature of Rubber Chemistry concludes the book.

In going through the book one cannot but be struck by the fact that it is extremely readable. Any chemist with some interest in rubber, whether his knowledge of rubber be specialised or not, must find it most interesting, instructive and stimulating. In each chapter the contributors have made a comprehensive and critical review of the available knowledge and without professing to be encyclopaedic have given very full references from which little of first importance can possibly have been omitted. In several cases the authors in summing up indicate the weak spots in our knowledge of the subject and point the way to possible fruitful researches of the future. Thus, in Chapter I by Van Rossem we read:—

> "No part of our knowledge of the chemical composition of crude rubber is more vague and disappointing in positive results than that regarding the proteins in rubber."

Similarly, in Chapter VI by Ira Williams the reader finds the following statement:—

> "A further study of the nature of unvulcanised rubber in regard to the structural unit and nature of association of these units must precede a final solution of vulcanization."

In Chapter XI by Shepard, Street and Park one reads:—

> "Enough moot questions have been raised and contradictions pointed out in this discussion to show the meagreness and insufficiency of our knowledge of reinforcement."

These authors then proceed to cite several specific directions in which research might profitably be conducted. Similar stimulating pronouncements occur in many other parts of the book. In several cases the authors are refreshingly outspoken in their conclusions. An instance of this appears in Chapter XI in which the following passage occurs:—

> "In many cases we are misled by incomplete, inadequate or even inaccurate data. Absurd and

> grossly stupid conclusions have resulted. In many cases, conflicting and irreconcilable opinions have been based on the same facts.'

In several parts of the book one finds sub-sections containing data which have not been collected together and presented so concisely in other books. An instance of this is noticeable in the very complete sub-section on tensile properties of raw rubber in Chapter II by Whitby.

Data previously unpublished are introduced in several places, of which one instance occurs on page 602 in the chapter on latex properties by Gibbons & Brass. Here the dependence of oxygen-absorption by latex on its pH value is presented for the first time.

Some overlapping of subject matter is noticeable. It is found for instance that some of the literature on X-ray studies on rubber is dealt with in Chapter II by Whitby and also by Fisher & Gerke in Chapter III. Similarly the fractionation and precipitation of rubber is discussed both by Busse in Chapter V and Whitby in Chapter II. There is also some duplication of subject matter in Chapters XIII and XIV by Dufraisse & Cotton respectively, and McPherson and Van Rossem overlap somewhat in Chapters XV and I in the particular respect of the water-absorption of rubber. It might be argued that the overlapping of subject matter constitutes a defect, but the present writer regards it on the contrary as an advantage; by its occurrence, each chapter has become complete in itself and readers whose special interest lies in one particular aspect of rubber chemistry can find it treated completely in the scope of a few pages; those on the other hand who wish to delve more deeply can find in such overlapping the advantage of slightly different viewpoints by two authors on the same subject matter.

Nothing beyond the most minor and unimportant criticisms of the book are possible. It is noticeable that different contributors present their bibliographies in different ways; some list authors' names alphabetically in the bibliography and others use consecutive numbers in the text which results in a non-alphabetic arrangement in the bibliography. The English subscribers are unanimous in the use of the second method. Both methods have their good and bad features however and the lack of uniformity is unimportant. It is somewhat unexpected to find the Peachey process included in Chapter VII on vulcanisation without sulphur, since although sulphur as such is not an initial ingredient, reactants are deliberately chosen which produce it *in situ*. In Chapter XX on synthetic rubbers no mention is made of the German post-war synthetic product, Buna. Precise information on its properties is not available and perhaps mention of it was excluded for this

reason, although its importance in this field is such that some mention of it would have been justified. In Chapter XXV on chemical analysis of rubber and latex, the tests on latex include only dry rubber-content and pH value; a little more space might perhaps with advantage have been given to latex-testing.

One error was detected on page 710 line 28 in which the word "calendar" should read "calender."

All rubber chemists will automatically acquire this book and none will be disappointed in it.

E. R.

Kuala Lumpur,

29th November, 1937

THE RUBBER RESEARCH INSTITUTE OF MALAYA

STAFF

January 1938

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Edited by H. J. Page on behalf of the Board of the Rubber Research Institute of Malaya.